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ABSTRACT

A project was conducted to develop a laboratory-based instructional system in physics for two-year technician programs that emphasizes both the analogies between basic physical principles and the applications of the principles in modern technology. The Unified Technical Concepts (UTC) system that was developed is (1) a reorganization of physics for practical interdisciplinary technician training, (2) a two-tiered series of modular instructional materials, and (3) a delivery system that incorporates module selection to tailor the courses to various student competencies and the technological requirements of a wide variety of specialized technician curricula. Thirteen concept modules form the backbone of UTC. Module titles include Force, Work, Rate, Momentum, Resistance, Power, Potential and Kinetic Energy, Force Transformers, Energy Convertors, Transducers, Vibrations and Waves, Time Constants, and Radiation. One hundred seventy application modules and eight supplementary modules complement the concept modules through the application of a single concept in a single energy system. Modules were pilot tested with students in programs at five schools and one employer site. Changes and additions were made based on the testing. (Appended material includes a description of the modules: an example concept module, application module, and support module: and a UTC short course for employed technicians.) (LRA)

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FINAL REPORT

PROJECT NO. 498AH70194
GRANT NO. G007701952

UNIFIED TECHNICAL CONCEPTS — PHASE II

Expand Application to Industrial Technologies and Adult Education

TECHNICAL EDUCATION RESEARCH CENTER — SOUTHWEST
4800 Lakewood Drive
Waco, Texas 76710

April 1980

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ABSTRACT

Unified Technical Concepts (UTC) is a new, practical approach for teaching physics to technicians. Since 1976, the U. S. Office of Education has awarded the Technical Education Research Center - Southwest two grants for research and developmental work on a UTC curriculum. The UTC-Phase I project determined the organizational structure for UTC, developed 130 modular instructional units (classroom and lab teaching materials for instructor and student), and determined the feasibility of using the delivery system in three pilot institutions. The UTC-Phase II project made major revisions to the UTC structure and existing modules, developed additional modules, and tested the materials, both in institutions and for use in retraining employed technicians.

The deliverables on this project (UTC-Phase II) include 191 developed and/or revised instructional modules, a 173-page UTC Instructor's Guide, a descriptive program brochure for dissemination, and a brochure to introduce UTC to the technical student.

Dissemination activities include: 1) eleven presentations at professional meetings or in journals, 2) displays at five state and national professional meetings, 3) a workshop for physics teachers from eight schools, and 4) an information mailing to 2800 schools, state directors of vocational and technical education, and directors of the national and regional curriculum coordination centers. The TERC-SW project staff provided assistance, upon request, to 202 educational and industrial planners and physics instructors. To date, 15 schools have implemented UTC, using a total of 9,371 instructional modules.

ACKNOWLEDGMENTS

This project was conceived out of needs expressed by many faculty members and administrators of two-year, postsecondary institutions, and out of the industrial experience of the Project Director; however, ideas for a unified approach to physics, presented as early as the turn of the century, were specified in 1972 in a curriculum development project for Electromechanical Technology, directed by Dr. Maurice W. Roney.

Encouragement to undertake the task of "restructuring physics" was provided by Dr. Walter J. Brooking, Technical Consultant, U. S. Office of Education. The project tasks have been conducted by the TERC-SW staff (Johnny Jones, Ellis Lindsey, Bruce Lube, and Vernon Woolf), assisted by Chief Technical Consultant and Editor, Dr. Leno S. Pedrotti, U. S. Air Force Institute of Technology. Pilot testing of instructional materials has been conducted at three innovative schools: Texas State Technical Institute, Harlingen, Texas; North Central Technical Institute, Wausau, Wisconsin; and Camden County College, Blackwood, New Jersey. Tests for retraining employed adult technicians were conducted by cooperation with the Los Alamos Scientific Laboratory, Ms. Maria Wolff Coordinator.

Sponsorship of this project was provided by a grant from the Research Division, U. S. Office of Education, Bureau of Adult and Occupational Education, Dr. Glen Boerrigter, Branch Chief.

Daniel M. Hull
Project Director

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INTRODUCTION

Complex, modern equipment often contains combinations of hydraulic, thermodynamic, pneumatic, or optical subsystems, as well as mechanical and electrical components. The subsystems and components appear, not in isolation, but as interdependent parts of such complex systems. Consequently, a modern technician must understand not only the separate subsystems, but also their interrelationships and the role they play in an integrated system.

Educational programs for preparing technicians should provide a broad, interdisciplinary technical base. This base should logically be developed when the students are introduced to the principles and concepts that form the foundation of the particular technical specialty - i.e., physics for the technical student.

The Unified Technical Concepts (UTC) approach to physics was conceived with the goal of developing modules that relate directly to applied physics, to industry, and to the technologies. This approach emphasizes both the analogies between basic physical principles and the applications of these principles in modern technology.

UTC is an alternate method of presenting what has been a formidable, and sometimes confusing subject for technicians. It provides laboratory experiments that apply to specific technological fields, allowing students to relate more quickly to module content: they understand how it affects them in their technology.

PRIOR WORK

Ideas for unification of physics date back to the turn of the century; however, details regarding specific design of such a plan were presented only a few years ago by Austin E. Fribance and Maurice W. Roney[1] in a project to develop a curriculum and supporting instructional materials for electromechanical technology (EMT). Soon thereafter, a theoretical text was pre-

[1]Project No. 8-0219, U. S. Office of Education Grant No. OEG-7-8000219-0057-(085), 1968 to 1973.

pared by James E. Court and Edward J. Dierauf[1] (out of necessity) to teach physics for students of electromechanical technology at City College of San Francisco. On July 1, 1976, the Technical Education Research Center - Southwest was awarded a grant (USOE No. G007603926) for the project entitled, "Modularizing Instructional Materials Using Applications of Technical Concepts." For the sake of clarity, this project will be referred to as "UTC - Phase I." The accomplishments of this project were the reorganization of physics into thirteen unified concepts, and the identification, development, field test, and dissemination of a series of approximately 130 instructional modules that present the thirteen concepts and illustrate applications of unified physics concepts. This project was completed in September 1978 and a final report describing the procedures and final products of this project can be obtained from the Technical Education Research Center - Southwest[2].

The application modules that were developed in UTC - Phase I were designed primarily to allow use of UTC in instructional programs for engineering technologies, i.e., electronics, electromechanical, instrumentation, etc. Furthermore, field testing of these materials had been conducted for only a short period of time and conclusive results relating to the usefulness of the materials and required revisions were limited.

PURPOSE OF RESEARCH PROJECT

The accomplishments of the UTC - Phase I project were the organization of technical physics into the thirteen concepts and the applications modules, the development of sufficient modules to test this delivery system in selected instructional programs, and an assessment of the interest in using this type of delivery system for technical physics in two-year, postsecondary technician programs throughout the country.

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[1]Dierauf, Edward J., Jr., and Court, James E. Unified Concepts in Applied Physics. Englewood Cliffs, NJ: Prentice-Hall, Inc., 1979.

[2]Unified Technical Concepts - Phase I, Final Report, Project No. 498AH60153, Grant No. G007603926, U. S. Department of Health, Education and Welfare, Office of Education, September 1978.

With the feasibility of UTC clearly demonstrated, additional research and program dissemination seemed appropriate to refine the instructional package, broaden the scope to other technologies being conducted at the same institutions, and to assure that the materials would be used in as many educational environments as possible, including adult education, or the training/retraining of existing employees. On October 1, 1977, the U. S. Office of Education, Bureau of Adult and Occupational Education, awarded the Technical Education Research Center - Southwest the grant (No. G007701952, project No. 498AH70194) for research entitled, "Unified Technical Concepts - Phase II - Expand Applications to Industrial Technologies and Adult Education." The project lasted until February 1980 and had four major objectives:

1. Revise the existing UTC structure as needed and develop additional application modules to extend the usefulness of the UTC physics to industrial and other technology programs.
2. Evaluate the usefulness of UTC materials for retraining employed (and recently unemployed) technicians for technical diversity and competencies in systems-oriented applications.
3. Conduct additional field tests of UTC materials to determine the effectiveness, and revise the materials according to the critiques.
4. Produce materials and conduct activities for disseminating UTC programs on a broad national basis.

Specific tasks of this project were:

Task 1 - Identify, develop, field test, revise, and disseminate one hundred additional application modules.

Task 2 - Assist, cooperate with, and support at least two postsecondary technical institutions in the implementation of the Unified Technical Concepts approach to physics instruction.

Task 3 - Assist, cooperate with, and support at least one employer organization in the implementation of a "systems technician" retraining program.

Task 4 - Prepare a Program Implementation Guide (40 to 50 pages in length) to assist schools and employers in implementing UTC programs.

The remaining sections of this report will document the changes brought

about by additional research for Task 1, accomplishments of the revised task, and the accomplishments of Tasks 2, 3, and 4, stated above.

DESCRIPTION OF THE FINALIZED UTC SYSTEM

Unified Technical Concepts (UTC) in its final version is 1) a reorganization of physics for practical interdisciplinary technician training, 2) a two-tiered series of modular instructional materials, and 3) a delivery system that incorporates module selection to tailor the courses to various student competencies and the technological requirements of a wide variety of specialized technician curricula. This section presents the stucture and implementation techniques of UTC.

STRUCTURE OF UTC

UTC consists of three types of modules - concept, application, and support. Refer to Table I for organization of module titles and to Appendix A for descriptions of each module. Each type of module is described below.

Concept Modules

Thirteen concept modules form the backbone of UTC. Each of these modules presents a single concept and discusses the application of that concept in each energy system.

1-0 FORCE

This module describes forcelike quantities as "the physical quantities that produce motion." The following forcelike quantities are discussed:

- Mechanical - force and torque.
- Fluidal - pressure difference.
- Electrical - potential difference.
- Thermal - temperature difference.

2-0 WORK

"Work" is defined as "the product of a forcelike quantity and a displacementlike quantity" in each energy system.

3-0 RATE

"Rate" refers to "the quotient of a displacementlike quantity and elapsed time" in each energy system.

4-0 MOMENTUM

"Momentum" is defined as "the product of mass and velocity" in mechanical and fluidal systems. Electrical and thermal systems are not discussed as momentum analogies because these systems are beyond the scope of UTC.

5-0 RESISTANCE

Static and sliding friction are investigated as examples of resistance in mechanical systems. For other energy systems, resistance is defined as "the ratio of forcelike quantity to rate."

6-0 POWER

"Power" is "the rate of doing work" in each energy system. The efficiency of devices that convert power from one form (energy system) to another is defined and discussed.

7-0 POTENTIAL AND KINETIC ENERGY

Concept Module 7-0 describes potential and kinetic energy in each energy system, the conservation of energy, and Bernoulli's Equation in fluidal systems.

8-0 FORCE TRANSFORMERS

"Force transformers" are defined as "devices that transform an input forcelike quantity and displacement into a different output forcelike quantity and displacement in the same energy system (levers, hydraulic jacks, electrical transformers)." Thermal systems are not discussed, as there are no transformers of temperature differnce.

9-0 ENERGY CONVERTORS

The operation and efficiency of devices that transform energy from one energy system to another are described in this module. A wide variety of energy convertors are discussed. Optical (light) energy is included in this concept as a fifth energy system.

10-0 TRANSDUCERS

Here, "transducers" are defined as "devices that change information-carrying signals in one energy system to signals in mechanical, electrical, or fluidal systems." The operations of several important transducers in each energy system are discussed as examples.

TABLE 1

SUPPORT MODULES	S1 Formula Interpretation S2 International System of Units S3 Logarithms and Exponents S4 Angles and Triangles	S5 Vectors and Scalars S6 Dimensional Analysis S7 Reading and Drawing Graphs S8 Precision, Accuracy and Measurement

CONCEPTS	**ENERGY SYSTEM**			
	MECHANICAL	**FLUIDAL**	**ELECTRICAL**	**THERMAL**
1-0 FORCE	**1-0 CONCEPT MODULE: QUANTITIES THAT CAUSE MOVEMENT**			
	1M1 Gravity 1M2 Addition of Mechanical Forces 1M3 Addition of Torques 1M4 Mechanical Equilibrium in Structures 1M5 Stress and Strain 1M6 Tension in Wires and Cables	1F1 Atmospheric Pressure 1F2 Density, Buoyancy, and Specific Gravity 1F3 Hydraulic Jack 1F4 Manometers	1E1 Potential Difference and Charge Flow 1E2 Series and Parallel Voltage Sources 1E3 Electric Forces and Fields 1E4 Magnetic Forces and Fields 1E5 Lead-Acid Storage Battery	1T1 Thermometers 1T2 Temperature Difference and Heat Flow 1T3 Thermal Stress
2-0 WORK	**2-0 CONCEPT MODULE: WORK = FORCELIKE QUANTITY X DISPLACEMENT**			
	2M1 Work Done on an Elevator 2M2 Work Done by a Winch	2F1 Work Done by a Water Pump 2F2 Work Done by a Hydraulic Lift		2T1 Heat Energy Required for a Temperature Increase 2T2 Heat Energy Required for Melting 2T3 Heat Energy Required for Boiling 2T4 Fundamentals of Air Conditioning
3-0 RATE	**3-0 CONCEPT MODULE: RATE = DISPLACEMENT / TIME ELAPSED**			
	3M1 Graphic Approach to Linear Motion 3M2 Velocity at Constant Acceleration 3M3 Displacement at Constant Acceleration 3M4 Acceleration of a Mass by Constant Force 3M5 Rotational Motion 3M6 Radial Acceleration and Centripetal Force	3F1 Flow Rate Measurement with a Venturi Meter	3E1 Electric Current 3E2 Frequency	3T1 Heating and Cooling Rate 3T2 Rate of Heat Conduction
4-0 MOMENTUM	**4-0 CONCEPT MODULE: FORCELIKE QUANTITY X TIME APPLIED = INERTIAL QUANTITY X RATE**			
	4M1 Angular Momentum of a Flywheel 4M2 Impulse and Momentum 4M3 Conservation of Momentum in Collisions 4M4 Gyroscopes	4F1 Rocket Engines		
5-0 RESISTANCE	**5-0 CONCEPT MODULE: RESISTANCE = FORCELIKE QUANTITY X RATE**			
	5M1 Static and Sliding Friction 5M2 Effect of Lubricants 5M3 Rolling Friction	5F1 Laminar and Turbulent Flow 5F2 Viscosity 5F3 Fluid Resistance in Pipes 5F4 Valves and Regulators 5F5 Shock Absorbers 5F6 Drag-Resistance to Motion Through Fluids	5E1 Ohm's Law 5E2 Series and Parallel Resistors 5E3 Internal Resistance of a Battery 5E4 Conductors, Semiconductors, and Insulators 5E5 Resistance of Wires 5E6 Resistance of Semiconductor Junctions 5E7 Resistance of Gas Laser Tubes 5E8 Volt-Ohm-Milliammeter	5T1 Thermal Conductivity 5T2 Heat Flow Through Insulation

6-0 POWER	**6-0 CONCEPT MODULE: POWER = WORK / TIME ELAPSED**			
	6M1 Horsepower 6M2 Prony Brake	6F1 Hydraulic Power	6E1 Electrical Power Measurement 6E2 Electric Heater 6E3 Efficiency of Electric Motors and Generators 6E4 Electrical Power Consumption	6T1 Heat Exchangers
7-0 POTENTIAL AND KINETIC ENERGY	**7-0 CONCEPT MODULE: CONSERVATION OF ENERGY**			
	7M1 Piledriver 7M2 Potential Energy of a Spring 7M3 Rotational Kinetic Energy of a Flywheel 7M4 Conservation of Energy in Collisions 7M5 Kinetic Energy and Horsepower of an Automobile	7F1 Energy Stored in Large Tanks 7F2 Venturi Meters 7F3 Pitot Tubes 7F4 Energy Conversion in Fluid Systems 7F5 Gas Laws 7F6 Siphons	7E1 Energy Stored in a Battery 7E2 Energy Stored in a Capacitor 7E3 Energy Stored in an Inductor 7E4 Series and Parallel Capacitors	7T1 Heat Storage Systems 7T2 Electrical Equivalent of Heat 7T3 Mechanical Equivalent of Heat 7T4 Thermal Drying 7T5 Mixing Liquids at Different Temperatures
8-0 FORCE TRANSFORMERS	**8-0 CONCEPT MODULE: PRINCIPLES OF SIMPLE MACHINES**			
	8M1 Levers 8M2 Wedges and Inclined Planes 8M3 Drive Systems 8M4 Gear Trains 8M5 Block and Tackle 8M6 Differential Hoist	8F1 Hydraulic Press	8E1 Electrical Transformers	
9-0 ENERGY CONVERTORS	**9-0 CONCEPT MODULE: DEVICES TO CONVERT ENERGY FROM SYSTEM TO SYSTEM**			
		9F1 Turbines 9F2 Fluid Pumps 9F3 Wind Power 9F4 Fans and Blowers 9F5 Vacuum Pumps	9E1 Electric Generators 9E2 Alternators 9E3 Electric Motors 9E4 Solenoids and Relays 9E5 Photovoltaic Materials	9T1 Boilers 9T2 Thermoelectric Generators 9T3 Solar Collectors
10-0 TRANSDUCERS	**10-0 CONCEPT MODULE: DEVICES TO TRANSFORM INFORMATION FROM ONE SYSTEM TO ANOTHER**			
	10M1 Strain Gages 10M2 Accelerometers	10F1 Bourdon Tubes 10F2 Aneroid Barometers 10F3 Differential Pressure Transducers 10F4 Fluid-Flow Measuring Devices 10F5 Vacuum Gages	10E1 Meter Movements	10T1 Automobile Thermostats 10T2 Bimetallic Strips 10T3 Temperature Measuring Devices 10T4 Thermocouples 10T5 Thermistors 10T6 Pyrometers
11-0 VIBRATIONS AND WAVES	**11-0 CONCEPT MODULE: MECHANICAL ENERGY TRANSFER THROUGH PERIODIC MOTION**			
	11M1 Speed of Sound in Materials 11M2 Reflection and Absorption of Sound Energy 11M3 Vibration Isolation 11M4 Resonance 11M5 Sound Speakers	11F1 Cavity Vibrations and Standing Waves 11F2 Speaker Enclosures 11F3 Reverberation Time 11F4 Doppler Effect 11F5 Pressure Measurement of Sound Waves	11E1 Alternating Voltage and Current 11E2 Phase Relationships in a.c. Circuits 11E3 Oscilloscope 11E4 Rectifiers 11E5 Electronic Filtering in d.c. Power Supplies 11E6 Electronic Filtering for Frequency Selection 11E7 Modulation of Electrical Waves	
12-0 TIME CONSTANTS	**12-0 CONCEPT MODULE: QUANTITIES VARYING EXPONENTIALLY WITH TIME**			
	12M1 Shock Isolation by Absorbers	12F1 Rate of Emptying Tanks	12E1 RC Circuits 12E2 RL Circuits 12E3 RLC Circuits	12T1 Response Time of Thermocouples 12T2 Time Constants of Heating and Cooling
13-0 RADIATION	**13-0 CONCEPT MODULE: ELECTROMAGNETIC AND PARTICLE RADIATION**			
	13L1 Inverse Square Law — Spreading of Light 13L2 The Optical Spectrum 13L3 Light Sources 13L4 Lasers 13L5 Stroboscopes — Light Pulses 13L6 Optical Filters — Absorption of Light 13L7 Specular and Diffuse Reflection of Light	13L8 Image Formation with Mirrors 13L9 Prisms — Refraction and Dispersion of Light 13L10 Lenses — Focusing and Spreading of Light 13L11 Interference — Testing Flat Surfaces 13L12 Diffraction Grating — Measuring the Wavelengths of Light	13L13 Polarization — Glare Reduction 13L14 Holography — Three Dimensional Photography 13L15 Spectroscopy — Light Analysis 13L16 Infrared Radiation Thermometers 13L17 Illumination 13L18 Single Lens Reflex Camera	13N1 Geiger Counters 13N2 Penetrating Power of Alpha and Beta Radiation 13N3 Radioactivity 13N4 Absorption of Gamma Radiation

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11-0 VIBRATIONS AND WAVES

The basics of wave behavior with examples in mechanical, fluidal, and electrical systems are explained. The discussion includes the wave equation, superposition, and interference of waves.

12-0 TIME CONSTANTS

In this module, an explanation is given of time constants used to describe exponential increase and decrease functions in all energy systems. Radioactive decay is included as an additional example.

13-0 RADIATION

Both electromagnetic and particle radiation are explored in this module, which is organized under these two topics rather than under the usual energy systems. Properties of electromagnetic radiation discussed include the inverse square law, polarization, reflection, and refraction.

Structure of Concept Modules

Each UTC concept module contains the following elements:

INTRODUCTION

Each concept module is introduced by a brief description of the concept to be discussed and includes examples of its application in the energy system to which it applies.

PREREQUISITES

A list of prerequisite UTC modules and any special knowledge or skills required for successful completion of the module is provided following the introduction.

OBJECTIVES

A number of specific tasks that students should be able to accomplish after the completion of the module are stated in behavioral terms. Some objectives are concerned with the unification of the concept in several energy systems; others apply to specific applications of the concept in a single energy system.

DISCUSSION

The Discussion is the "text" of the module and begins with the definition of the concept as it applies in all energy systems to be considered. Applications of the concept are discussed in each energy system, to-

gether with the use of appropriate equations, figures, tables, example problems, and practical technical applications. All appropriate units are defined for each energy system. The order of energy systems in most concept modules is (1) mechanical, (2) fluidal, (3) electrical, and (4) thermal.

SUMMARY

Immediately following the Discussion in each concept module is a Summary, which stresses unification by explaining the similarity of the concept as it applies in different energy systems.

DEMONSTRATIONS

The Demonstrations section contains the materials and procedures necessary for performing classroom Demonstrations that illustrate the applications of the concept in each energy system. Spaces are provided for students to record data and results when appropriate. Some Demonstrations are simple and quickly performed, although others are more complicated and can be used as student exercises.

SELF CHECK

The Self Check consists of a set of problems and questions based upon the module Objectives and intended for use by students to check their own understanding of the module content.

REFERENCES

The References are bibliographical sources that direct students to additional information on topics discussed in the module.

An example of a concept module is presented in Appendix B.

Application Modules

Each of the 170 application modules discusses the application of a single concept in a single energy system. The elements of an application module are the same as those of a concept module. The following comments apply to the sections of UTC application modules:

The INTRODUCTION identifies the concept and explains how it applies to the particular application to be discussed.

PREREQUISITES always include the concept module under which the application module is listed.

OBJECTIVES include the completion of one or more laboratory exercises by the students.

The DISCUSSION includes both practical examples and the development of the theory upon which the laboratory is based.

The SUMMARY is an overview of the module and includes a reference to the concept being demonstrated.

The LABORATORY replaces "Demonstrations" and consists of one or more hands-on experiments.

The SELF CHECK provides problems and questions concerning the application of the concept.

REFERENCES indicate sources of additional information concerning the application of the concept and of the devices discussed in the module.

Application modules are identified by a number that indicates both their concept and energy system. 5M3, "Rolling Friction," for example, is the third (3) mechanical (M) application module listed under Concept 5-0, "Resistance." This system indicates that Concept Module 5-0 is prerequisite to 5M3, but that 5M1 and 5M2 are not necessarily prerequisites. Figure 1 clarifies both this numbering system and the basic structure of UTC.

UTC application modules may be categorized in several ways. One of the following descriptive phrases applies to the topics presented in each application module (an example of each type is included):

An expansion of the physics discussed in the concept module, usually including a more detailed mathematical description (1M3, "Addition of Torques").

The investigation of a phenomenon based upon the concept (5E5, "Resistance of Wires").

The description and operation of a device based upon the concept (5F5, "Shock Absorbers").

A description of the application of the concept within a subsystem of some larger system (6F1, "Hydraulic Power").

An example of a UTC application module is presented in Appendix C.

CONCEPT MODULE	CONCEPT 1-0 FORCE			
	Force and Torque	Pressure Difference	Potential Difference	Temperature Difference
ENERGY SYSTEMS	MECHANICAL	FLUIDAL	ELECTRICAL	THERMAL
	1M1 Gravity 1M2 Addition of Mechanical Forces 1M3 Addition of Torques 1M4 Mechanical Equilibrium in Structures 1M5 Stress and Strain	1F1 Atmospheric Pressure 1F2 Density, Buoyancy and Specific Gravity 1F3 Hydraulic Jack 1F4 Manometers	1E1 Potential Difference and Charge Flow 1E2 Series and Parallel Voltage Sources 1E3 Electric Forces and Fields 1E4 Magnetic Forces and Fields 'E5 Lead-Acid Storage Battery	1T1 Thermometers 1T2 Temperature Difference and Heat Flow 1T3 Thermal Stress

Figure 1.

Support Modules

The following eight support modules provide necessary background material in their respective areas and explain its application in UTC:

S1 Formula Interpretation.
S2 International System of Units.
S3 Logarithms and Exponents.
S4 Angles and Triangles.
S5 Vectors and Scalars.
S6 Dimensional Analysis,
S7 Reading and Drawing Graphs.
S8 Precision, Accuracy, and Measurement.

The structure of support modules is the same as that of UTC application modules. The laboratory exercises require the use of pencil, paper, calculator, and measuring and graphing tools.

An example of a UTC support module is presented in Appendix D.

IMPLEMENTATION OF UTC

The first step in implementing UTC is to identify the technologies to be served. When the technologies have been determined, the physics instructor is encouraged to consult with instructors of the technologies to select appropriate modules for their students. Since the technology instructors probably lack familiarity with UTC, the physics instructor should be prepared to recommend specific modules to meet the needs expressed by technology instructors. Implementation techniques and module selection methodologies are described in detail in the UTC Instructor's Guide.

Concept selection and order can be varied with the aid of Figure 2. The following suggestions should be considered carefully:

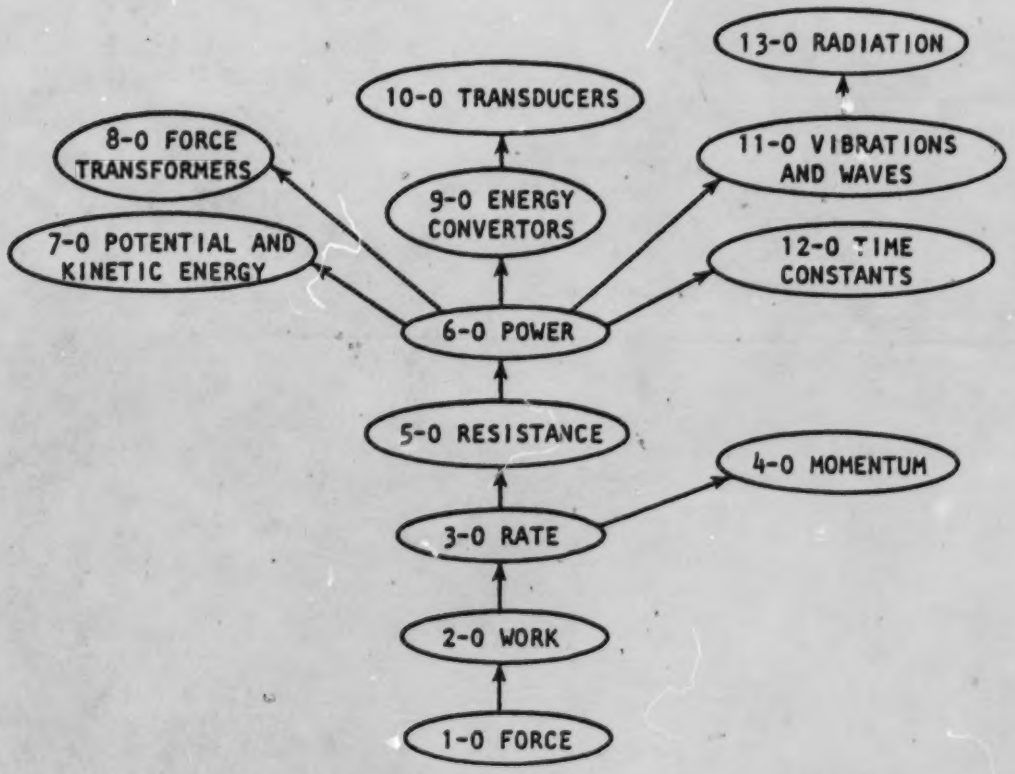

Figure 2. Concept flow chart.

Concepts 1-0, 2-0, 3-0, 5-0, and 6-0 form a linear sequence and should be presented in that order. All students taking UTC should study these five concepts as a minimum.

Concept 4-0, "Momentum," can be studied anytime after 3-0, "Rate," but often is deleted in favor of concepts of greater relevance.

After Concept 6-0, "Power," any order may be chosen, provided that 9-0 precedes 10-0 and that 11-0 precedes 13-0. This flexibility allows later concepts to be ordered in such a manner as to meet prerequisites for courses taken concurrently with UTC

Once the concept modules have been selected, appropriate application modules are chosen. Module prerequisites should be checked carefully, as some application modules have as prerequisites application modules from earlier concepts. The following two notes are important in the selection of application modules:

Application Modules 1E3, "Electric Forces and Fields," and 1E4, "Magnetic Forces and Fields," are prerequisite to many application modules and to Concept Module 13-0, "Radiation."

Some application modules that describe measuring equipment may be presented effectively before their concepts in order to familiarize students with equipment. These modules include 5E8, "Volt-Ohm-Milliammeter," and 11E3, "Oscilloscope."

Support modules may be presented at any time, but are most effective if studied concurrently with related material in concept and application modules.

PRESENTATION OF UTC

UTC is an extremely versatile package and may be taught in a variety of ways. The following points should be considered in the planning of teaching strategies for UTC:

- Concept modules are designed for lecture presentation. The appropriate sections of each concept module should be discussed in class before students perform laboratory exercises based upon that concept.

- Some application modules should be discussed in class before students attempt the laboratory; others can be presented easily as self-paced laboratory exercises.
- Instructors are encouraged to review all materials and to determine the best approach for each class.
- Students from different technologies may study different applications of the same concept during one laboratory period. This enhances learning by allowing students to observe experiments that they themselves do not perform.
- Several different application module experiments can be set up within a single lab in which students perform experiments in rotation. This method allows fewer lab stations for each module.
- Most experiments in UTC can be set up by the students, but a few require more complicated setups that must be provided.
- Students should be encouraged to answer all Self Check questions and to work all problems.
- Testing should be based upon module objectives. Instructors adding or deleting material are encouraged to inform students of the addition or deletion of objectives.
- UTC modules contain space for the recording of experimental data, but no specific instructions on laboratory reports are given. Such instructions are left to the discretion of the instructor.
- The instructor is urged to point out analogies between various energy systems at every opportunity. Unification should be stressed particularly at the beginning and end of the presentation of each concept module. Appendix E, "Concept Module Summary Charts," contains a summary chart of each concept module to be used for this purpose.

PROJECT ACTIVITIES/RESULTS

Research to accomplish Task No. 1 (identify and develop 100 additional modules to extend the usefulness of UTC to industrial technology and other occupational programs) revealed that many of the occupational areas (such as Dental Laboratory, Welding, etc.) did not require sufficient treatment of physics to justify the use of a comprehensive program like UTC. Furthermore, the results of Phase I pilot testing at three schools indicated that several major changes were needed in the structure of the UTC modules and delivery system, and more application-level modules were needed to complement the engineering technologies and to tailor UTC to support several "energy-related" technologies*.

Upon the advice of the Project Advisory Committee and the faculty at the pilot-test sites, the "Program Implementation Guide" was renamed the "UTC Instructor's Guide" and was expanded in size to 175 pages to include all module descriptions, concept charts and solutions to module "Self Check" problems.

After discussion of these changes with the USOE Technical Consultant, Dr. Walter Brooking, and USOE Program Management, two of the tasks were revised to read:

Task 1 - Revise the UTC structure as needed, including major revisions to Phase I modules and development of new modules. The total number of new and revised modules should be 190 to 200.

Task 4 - Prepare a UTC Instructor's Guide (170 to 180 pages in length) to assist schools and employers in implementing UTC programs.

USE OF PROJECT ADVISORY COMMITTEE AND CONSULTANTS

The overall direction and review of this project was provided by a Project Advisory Committee, whose members are listed in Table II. The UTC Project Advisory Committee was an active and working group, consisting of

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*A more detailed explanation of these changes is included in Section IIIB, "Instructional Materials Development/Revision."

TABLE II

UTC PROJECT ADVISORY COMMITTEE

Mr. Daniel M. Hull, Chairman
General Manager
Technical Education Research Center - Southwest
Waco, Texas

Mr. Oscar Hinojosa
Manager of Curriculum and Instruction
Texas State Technical Institute
Harlingen, Texas

Mr. Dwain Ingram
Technical Physics Instructor
Texas State Technical Institute
Waco, Texas

Mr. James R. Johnson
Technical Science Instructor
North Central Technical Institute
Wausau, Wisconsin

Mr. Johnny E. Jones
Associate Project Director
Technical Education Research Center - Southwest

Mr. Carl Lansford
Technical Science Instructor
Texas State Technical Institute
Harlingen, Texas

Dr. Leno S. Pedrotti
Chairman
Department of Physics
U. S. Air Force Institute of Technology
Dayton, Ohio

Father Frank Pedrotti
Research and Physics Faculty
Marquette University
Milwaukee, Wisconsin

Dr. John D. Pierson
Manager of Instructional Personnel
Texas State Technical Institute
Waco, Texas

Mr. Fred Seeber
Associate Professor of Physics
Camden County College
Blackwood, New Jersey

Mr. Don Tatum
Physics Instructor
McLennan Community College
Waco, Texas

technical experts, school administrators and faculty, including those at the five schools pilot testing the materials. Their major responsibilities included:

1. Review of project accomplishments and recommendations for changes in project direction or activities.
2. Review of titles and content for modules to be developed.
3. Review of proposed module revisions.

4. Review and critique of module drafts.
5. Recommendations and reviews for content and draft of UTC Instructor's Guide.
6. Recommendation and review of dissemination activities, including UTC information brochures.
7. Pilot test and critique of materials in school programs.

The Committee met three times during the project, as described in Table III.

TABLE III

UTC-II PROJECT ADVISORY COMMITTEE MEETINGS

Date	Location	Accomplishments and Recommendations
1/29-30/78	Waco	•Recommended shifting module development emphasis from supporting lower-level programs to "filling gaps" in support of engineering technologies. •Recommended development of UTC Instructor's Guide. •Approved module titles and content. •Discussed pilot-test results - need for support modules in math, units, etc.
6/26-27/78	Waco	•Discussed pilot-test requirements for fall. •Approved new UTC structure to include concept, concept support, application, and supplementary modules. •Approved module titles and content. •Reviewed and critiqued Instructor's Guide. •Discussed applications of UTC in adult education.
1/4-5/79	Waco	•Reviewed student brochure. •Reviewed Instructor's Guide. Recommended solutions to problems be included. •Approved final revisions to modules. •Approved final list of modules. •Discussed UTC adult education course at LASL. •Discussed UTC in Energy Conservation curriculum and summer workshop.

In addition to the time spent at the meetings, members of the Project Advisory Committee reviewed and critiqued modules and the Guide sent to them by mail. It is estimated that the collective time donated to this project by the Advisory Committee members exceeded 1000 hours.

Evaluation of the UTC structure and all instructional modules for technical accuracy, content, and acceptability in the physics community was performed by the following technical consultants:

Dr. Leno S. Pedrotti, Chairman, Physics Department
U. S. Air Force Institute of Technology, Dayton, Ohio

Father Frank Pedrotti, Research and Physics Faculty
Marquette University, Milwaukee, Wisconsin

A report of the project consultants/editors is included in Appendix F.

INSTRUCTIONAL MATERIALS DEVELOPMENT/REVISIONS

During the first several months of the project, a concerted effort was made to determine the content of physics (and more specifically the new module topics) that would be used in vocational/technical curricula other than those selected in UTC Phase I.

School catalogs were studied, physics teachers were interviewed, task analyses were requested from faculty in vocational/technical programs, and schools were visited. The findings of this research were that some technologies do not require an interdisciplinary approach to physics and that UTC is too comprehensive to meet their limited needs. Among the technologies in this category are:

Dental Laboratory.
Auto Mechanics.
Welding.
Machine Shop.
Civil Technology.
Radio/Television Repair.
Automatic Merchandising Machines.
Auto Body Repair.

On the other hand, UTC was found to be ideally suitable for other technologies, including (but not limited to):

Electrical Power.
Drafting and Design.
Electronics.
Instrumentation/Control.
Laser/Electro-Optics.
Biomedical Instrumentation.
Energy Research/Development.
Electromechanical.
Air Conditioning/Refrigeration.
Computer Hardware.
Energy Conservation.
Electrical Power Plant Operation.
Nuclear Technology.

Based on the results of this investigation and the demonstrated need by pilot-test sites for module changes and a reorganization of the UTC structure, a decision was made to develop fewer new modules and perform major revisions to existing ones developed in UTC Phase I.

The following changes, approved by the Advisory Committee, were made to the UTC organizational structure:

1. Concept Module 1-0, entitled "Matter, Units and Measurements," was eliminated.
2. Information contained in the concept module, "Matter, Units and Measurements" was placed in newly developed support modules.
3. Eight support modules were developed and/or revised for use by the instructor whenever in the course of instruction it was appropriate that the students needed this information.
4. Concept 10-0, entitled "Energy Transformers," was divided into two concepts - "Transducers" and "Energy Converting Devices."
5. Modules on Nuclear Physics were added in Concept 13-0, entitled "Electromagnetic and Particle Radiation.
6. A "Self Check" section for practice problems was added to previously developed and new application modules. Solutions to all Self Check problems were prepared.
7. All laboratory activities in the previously developed concept modules were converted to class demonstrations.

8. Additional physics topics that did not "fit well" into the concept modules were presented as "application level" modules. Examples are 2E3, "Magnetic Force," and 2E4, "Electric Force." (These are modules on electric and magnetic fields.)

Additional new modules were developed to complete physics requirements in the relevant technologies by "filling the gaps" identified by the pilot-test sites. The total number of 191 revised and newly developed modules (all delivered as project end items for UTC Phase II) is shown in Table 1 (p. 7).

PILOT TESTING INSTRUCTIONAL COURSES AND MATERIALS

UTC materials were tested with students in pilot programs at five schools and one employer site. The purpose of this testing was to answer the following questions:

1. Is student reaction to and performance of UTC generally more positive and productive than previously used physics texts?
2. Is the unification concept grasped by students? How quickly?
3. Do students of UTC generally perform better in more advanced technology courses requiring physics as a prerequisite?
4. Is UTC effective in retraining employed adult technicians to broaden their technical base?
5. What deficiencies exist in modules? How can modules be revised to provide more effective instruction? What additional modules are needed? Is the sequence of concepts correct?
6. How long does it take to teach UTC; i.e., how many modules per concept, in what time span?

Because of time limitations, the need to secure approvals for obtaining student performance data, and the difficulty in establishing control groups, most of the results from this test activity are subjective and nonquantitative. Nevertheless, the pilot test experience provided some confidence as to the success of the project and invaluable data for module revisions.

Testing at Schools

In the 1978-1979 school year, five institutions used UTC for teaching technical physics (see Table IV). The faculty at these schools were all members of the Project Advisory Committee and, being familiar with the UTC program, required no workshop.

TABLE IV

INSTITUTIONAL PILOT TESTING IN 1978-1979

Institution	Faculty Member	No. of Students	Program Major	UTC Modules Selected
Texas State Technical Institute - Harlingen	Carl Lansford	12	Building Construction	All concepts & selected applications
		25	Diesel Mechanics	
		30	Drafting	
		35	Electronics	
North Central Technical Institute	James Johnson	20	Laser	All concepts & selected applications
Camden County College	Fred Seeber	18	Opthalmic Science	All concepts & selected applications
Texas State Technical Institute - Amarillo	Delvin Harmes	9	Drafting & Design	Concept Modules 2 through 6 & selected applications
Texas State Technical Institute - Waco	Tom Bills	20	OSHA	Concept Modules 1 through 7 only - no applications

The field-test review instruments used are included in Appendix G. Results of testing in the first three institutions, as recorded in these

instruments and from personal interviews conducted by the project staff, indicate that students like the UTC physics, performed better than previous classes using other texts, and grasped the unification idea by the time they were in the second or third concept. At North Central Technical Institute, James Johnson taught not only the UTC physics but also the technical specialty courses in Laser/Electro-Optics. He indicated that the students from UTC were "better prepared" and learned quicker in the laser courses than earlier groups of students with a more traditional technical physics background. Laser Technology is a typical example of a modern, interdisciplinary technology.

Results of using UTC in the course for OSHA students were not as positive. The opinion of the faculty member was that the students did not grasp physics as well or as quickly as he had expected. This is the only instance in institutional usage of UTC where only the concept modules were used (no application modules). It is concluded that students without prior physics background should not be taught UTC without application modules.

Critiques of the specific modules used indicated several areas where they required revisions for clarity, additional explanations, corrections in text and problems, and improvements or replacements in laboratory activities.

In the following year, Technical Education Research Center - Southwest was field testing recently developed curriculum materials for Energy Conservation-and-Use Technicians (ECUT) - a broad, interdisciplinary curriculum, designed under USOE contract No. 300780551. UTC is a key component of the ECUT curriculum, and is vital to the broad technical base needed for these technicians. The four schools that began using UTC in the ECUT curriculum are listed in Table V.

The TERC-SW staff selected 107 UTC modules to be taught to the ECUT students (see Appendix G). The TERC-SW staff recommended that UTC courses be scheduled for three hours classroom and six hours laboratory per week for the entire first year (three quarters or two semesters) for a total of 324 contact hours. A workshop for the new faculty was held at Camden County College in Blackwood, New Jersey, June 27 and 28, 1979. A thorough understanding of the UTC organization and teaching techniques is essential in this very different approach to technical physics.

TABLE V

INSTITUTIONAL PILOT TESTING IN 1979-1980

Institution	Faculty	No. of Students	Modules Used
Horry-Georgetown Technical College	Wade Harper	26	ECUT requirements. See listing, Appendix G.
Marshalltown Community College	Arlen Hackbarth	12	ECUT requirements. See listing, Appendix G.
Red Wing Area Vocational Technical Institute	Pat Enz	25	ECUT requirements. See listing, Appendix G.
Tacoma Community College	Ivonna McCabe	18	ECUT requirements. See listing, Appendix G.

This group of schools trying UTC was particularly important in the program evaluation because, for the first time, they represented schools and faculty that were previously unfamiliar with UTC. Overall, the reaction of the faculty and students to UTC was positive (all the schools plan to use it again in 1980-1981). However, several errors were found in the modules and all the faculty felt that the number of practice problems (Self Check section) should be increased significantly in most application modules. This is being done by TERC-SW, even though project funding has been exhausted.

Recall that the recommended time for teaching 12 concept plus 83 application modules was 9 hours per week for an entire year (approximately 30 weeks of actual instruction). Each application module should require an average of two hours (one hour for discussion and one hour for laboratory). In practice, the application modules required more discussion, primarily in the allotted classroom time, to relate the applications to the concept under study. Classroom time is also required to present the sup-

port modules (numbered S-1 through S-8). These support modules, providing basic technician skills/knowledge and summarizing important math skills, were all used by all the schools; some schools spent considerable time on the support modules, probably because of lower student competencies.

Not all the schools implementing the ECUT curricula scheduled the classroom and laboratory time recommended for teaching the 107 UTC modules. Two of the schools allotted three classroom hours per week but only three laboratory hours per week instead of six. These schools found that they could not cover all the recommended work and either did not complete the 12 concepts or taught fewer application modules. Their plans this next year are to teach all 12 concepts, but to include only an average of four application modules per concept.

Based upon the experiences of the schools that have used UTC for the past several years and recognizing that more materials can generally be covered effectively after the faculty member has at least one year of experience with the UTC material, an estimate can be made of the depth of UTC to be taught for several typical schedules. This is presented in Table VI.

RETRAINING EMPLOYED ADULTS

During the period January 8 through 12, 1979, the TERC-SW staff conducted a five-day short course using UTC concept modules to retrain employed adult technicians at Los Alamos Scientific Laboratory (LASL). LASL employs approximately 5000 scientists, engineers, and technicians to conduct for the U. S. Department of Energy advanced research and development on thermonuclear weapons and new energy resources. LASL is operated in Los Alamos, New Mexico, by the University of California, and is recognized as one of the nation's leading employers of high-level scientific personnel. Nearly all of the scientists and engineers have advanced degrees (most at the PhD level). Technicians work in laboratories, directly supporting engineers and scientists. Many of the employed technicians have been working on thermonuclear weapons design/development and recently have been transferred to new jobs in energy resources development in areas such as laser-induced thermonuclear fusion or isotope separation.

TABLE VI

RECOMMENDED SCHEDULES FOR UTC INSTITUTIONAL INSTRUCTION

Period Offered	Weekly Schedule		Concept Modules	Application Modules	Support Modules
	Class	Laboratory			
Full year (3 quarters or 2 semesters)	3 hr	6 hr	12 or 13	70-80 (Avg. 6 per concept)	As needed
Full year (3 quarters or 2 semesters)	3 hr	3 hr	12 or 13	45-55 (Avg. 4 per concept)	As needed
Half year (1 semester)	3 hr	6 hr	7 (#1-7)	35-40 (Avg. 5 per concept)	As needed
Half year (1 quarter)	3 hr	3 hr	7 (#1-7)	22-28 (Avg. 3-4 per concept)	As needed
Two quarters	3 hr	6 hr	9 (#1-7, 11, 13)	54-60	As needed
Two quarters	3 hr	3 hr	9 (#1-7, 11, 13)	36-40	As needed
One quarter	3 hr	6 hr	5 (#1-3, 5, 6)	25	As needed
One quarter	3 hr	3 hr	5 (#1-3, 5, 6)	18	As needed

The UTC course was conducted at a nearby college physics laboratory in Santa Fe, New Mexico. The instructor was Mr. Johnny E. Jones, a TERC-SW staff member who directed the UTC module revisions. Mr. Jones has four years of experience teaching physics and laser/electro-optics at a post-

secondary technical institute and over three years of experience teaching short courses on other topics for employed technicians, including several technicians at LASL.

Twenty students participated in the course. They came from diverse job situations and had a wide range of physics backgrounds. Work areas represented included electronics, lasers, drafting, mechanical, explosives testing, and chemical. Five students had never received formal physics training. One had previously taught physics in high school, and another was a senior technician with several college courses and a firm grasp of the subject.

Prerequisites for UTC modules include a working knowledge of basic algebra. The twenty students were selected from a group of forty candidates by administering a basic algebra test and eliminating all candidates who did not correctly answer twenty out of forty questions. The algebra tests that assessed the mathematical skill level of potential students were administered to ensure this competence. Several standardized tests were evaluated by the project staff and recommended to the LASL course coordinator prior to the course. Form A, Algebra I of the Cooperative Mathematics Tests series published by the Educational Testing Services, Princeton, New Jersey, was selected and administered to the candidates for the LASL course. The reliability of Form A of the Algebra I test was established as 0.85 to 0.86, determined by using the Kuder-Richardson Formula 20 for internal consistency. Reliabilities in that range assure the user that data obtained represent the mathematics capability of the student.

The course schedule is presented in Appendix H. The course content consisted primarily of the material in the thirteen concept modules with selected demonstrations. Thirty-five hours of instruction were provided in five days. Pretests and posttests of UTC were administered (copy included in Appendix H). The results of the test scores, along with the algebra test scores for the twenty students are presented in Table VII. A perfect UTC test score is 23; the average pretest score was 8.0 and the average posttest score was 13.3.

The course was well received, not only by the students but also by the several technician supervisors, the LASL training coordinator, and faculty of nearby schools who observed on one or more days. A tabulated

TABLE VII

TEST RESULTS ON UTC SHORT COURSE FOR
EMPLOYED TECHNICIANS AT LOS ALAMOS SCIENTIFIC LABORATORY

Employee Number	Algebra Test* Score (Perfect Score 40)	UTC Pretest** (Perfect Score 23)	UTC Posttest (Perfect Score 23)
1	35	18	21
2	32	16	21
3	31	--	14
4	30	8	14
5	29	10	11
6	29	3	13
7	28	12	17
8	28	--	16
9	27	6	14
10	27	4	13
11	26	7	11
12	26	9	11
13	26	5	8
14	26	--	17
15	25	0	10
16	25	6	18
17	21	--	10
18	21	6	13
19	20	10	8
20	20	8	10

*Form A, ALGEBRA I, Cooperative Mathematics Test. Princeton, NJ: Education Testing Services, 1962.

**Prepared by Technical Education Research Center - Southwest (copy attached).

critique of the course and student comments are included in Appendix H. Overall, the use of UTC to retrain and broaden employed adult technicians was judged as highly successful, even though there are no clear ways to measure the benefits of this instruction on job performance.

The course probably will be repeated sometime in 1980 with the following changes:

- At least twice as much time should be allotted to conduct the course.
- Add more demonstrations, problem-solving sessions, and discussion of concept support modules such as Electric Fields and Magnetic Fields.
- Send all eight support modules to students to study prior to the course; if students have problems reviewing any of the topics, the students or the entire class should be tutored prior to teaching UTC.

DISSEMINATION ACTIVITIES

Project dissemination includes plans, key individuals and organizations, informational materials, guides, and activities that enable and assure that the UTC program, classes, and instructional modules are used by institutions, employers and other organizations to train/retrain students for a broad base in technology through technical physics. This section of the report will describe the developed support materials, visibility activities, and staff responses to inquiries about potential UTC usage.

Dissemination Support Material

A Program Information Brochure was prepared to briefly describe the purpose, rationale, format, and optional uses of the UTC system. The back side of the brochure lists the 191 concept and application modules along with information about cost and availability. This brochure addresses educational administrators, planners, and faculty at technical institutes, community colleges, vocational high schools, and employer training specialists. Four thousand copies were printed, two color, on a single sheet of 8½-inch by 11-inch litho coated stock. The brochures have been distributed at meetings, in presentations, and in response to inquiries about the

program materials. A copy of the brochure is included in Appendix I.

A 175-page UTC Instructor's Guide was prepared to familiarize a teacher using UTC with the system design, materials selection process, and methods of presentation. Pilot-test experiences in UTC Phase I and UTC Phase II demonstrated the vital requirement for instructors of UTC to be convinced of the need for unification in technical physics and the ways to stress this aspect of the program in the instructional process. The Guide describes the system and each type of module, provides summaries of all 191 modules and a module selection matrix ("shopping list"), and includes solutions to all problems in the module "Self Check" exercises. Concept Module Summary Charts are also included, as well as sample copies of a concept module and an application module. Copies of the UTC Instructor's Guide are distributed upon request to faculty and administrators who plan to use UTC modules.

A UTC Student Orientation Brochure was prepared to explain to each student the need for technical physics as a vital technical base from which to learn and use the technical specialization related to his/her future job. The brochure also explains UTC, the concept and application modules, and how to look for the unification principles. Two thousand copies of this "student motivational" brochure were printed, two color, on both sides of 8½-inch by 14-inch litho coated stock. They are included with every set of UTC modules ordered. A copy of the UTC Student Orientation brochure is included in Appendix I.

Program Visibility Activities

1. An inquiry of interest about UTC physics was mailed to 2800 schools, state directors of vocational/technical education, and directors of the national and regional curriculum coordination centers. 146 responses to this inquiry were received, requesting information about the program and instructional materials. Each of these respondents was sent a UTC Program Information brochure.
2. An article describing the UTC program and instructional materials is scheduled to appear in the May 1980 issue of CRPTYC, the newsletter of the American Association of Physics Teachers.

3. A paper entitled "Preparing Technicians for Energy-Related Occupations" was presented to the Seventeenth Annual National Conference on Technical Education, sponsored by the American Education Association, Technical Education Division, American Vocational Association, and U. S. Office of Education, on March 27, 1980. A copy of the program for this conference is presented in Appendix I. UTC Program Information brochures were distributed at this meeting.
4. The UTC program and instructional materials were described by the TERC-SW staff at the U. S. Office of Education, Energy Action Center's workshop on Training to Meet Energy Workforce Needs, in Washington, DC, February 27 through February 29, 1980. Copies of the UTC Program Information brochure were distributed.
5. The UTC program and instructional materials were described by the TERC-SW staff at the American Vocational Association National Energy Conference in Washington, DC, January 28, 1980. Copies of the UTC Program Information brochure were distributed.
6. A paper entitled, "UTC Physics - A Broad Technical Base for Energy Technicians," was presented to the meeting of the American Association of Physics Teachers on January 23, 1980, by Project Director Mr. Daniel M. Hull and Dr. Leno S. Pedrotti, Professor of Physics, Air Force Institute of Technology, and UTC project Technical Advisor. A partial program for this meeting and an abstract of the paper are included in Appendix I. UTC Program Information brochures were distributed at this meeting.
7. On November 16 and 17, 1979, the TERC-SW project staff displayed and distributed information on UTC to the Technical Education Conference of the Texas Technical Society.
8. In August 1979, Dr. Leno S. Pedrotti, project consultant, presented the UTC project and instructional materials before the faculty of the Physics and Engineering Departments at the U. S. Air Force Academy at Colorado Springs, Colorado.
9. A workshop was held June 27 and 28, 1979, at Camden County College in Blackwood, New Jersey, for faculty from the following schools, which were to implement UTC instruction in the fall of 1979:

Colorado Northwestern Community College.
Trident Technical College.
Tacoma Community College.
Marshalltown Community College.
916 Vo-Tech Institute.
Horry-Georgetown Technical College.
Greenville Technical College.
Miami-Dade Community College.

10. An article by the Project Director entitled, "Technical Education to Meet New Demands in Energy," was published in the May 1979 issue of Engineering Education. Information about the UTC program was mentioned in this article.
11. On December 1, 1978, the Project Director presented the UTC program to the Board of Trustees of the American Technical Education Association meeting in Dallas, Texas.
12. A paper entitled, "Teaching More Physics in Less Time by Unifying Its Concepts," was presented to the meeting of the American Association of Physics Teachers on June 14, 1978, by Mr. Carl E. Lansford, former TERC-SW UTC Associate Project Director and now Instructor of Physics at Texas State Technical Institute Harlingen Campus. UTC Program Information brochures were distributed at this meeting.
13. UTC materials were displayed at the 26th Annual Physics Show in conjunction with the combined annual meeting of the American Physical Society and the American Association of Physics Teachers in San Francisco, California, on January 23 through January 25, 1978.
14. UTC was presented to the American Technical Education Association in a paper by the Project Director entitled, "Knitting Together Technologies for Energy Needs in the Third Century." This meeting took place im Memphis, Tennessee, on March 24, 1977.
15. In 1977, Mr. Carl E. Lansford presented a paper titled, "A Unified Approach for Teaching Physics," at a joint meeting of the Texas Section of the American Association of Physics Teachers and the Society of Physics Students, in Dallas, Texas. Copies of the UTC Program Information brochure were distributed.

Responses to Inquiries and Requests for Assistance

The following individuals and/or organizations requested and received information from the project staff (in addition to the Program Information brochure) about using UTC materials in technical physics courses:

Mr. Bob Anderson
Los Alamos Scientific Laboratory

Mr. Tom Bills
Texas State Technical Institute
Waco, Texas

Mr. Jerry Branson
Texas State Technical Institute
Sweetwater, Texas

Dr. Horace W. Chandler
Bergen Community College
Paramus, New Jersey

Dr. Curtis W. Cox
Southwest Virginia Community College
Richland, Virginia

Mr. Joe H. Cunningham
Community College of Denver
Golden, Colorado

Mr. Ronald DeSpain
Texas State Technical Institute
Amarillo, Texas

Ms. Pat Enz
Red Wing Energy Education Center
Red Wing, Minnesota

Mr. Arlen Hackbarth
Marshalltown Community College
Marshalltown, Iowa

Mr. Delvin Harmes
Texas State Technical Institute
Amarillo, Texas

Mr. Mark Hemmes
Optics and Electronics
Richardson, Texas

Mr. Bruce Hendler
Bellingham, Washington

Mr. Robert Hetzel
Chicago Vocational High School
Chicago, Illinois

Mr. Dwain Ingram
Texas State Technical Institute
Waco, Texas

Mr. Russell Johnson
Solono Community College
Suison City, California

Mr. Fritz Kissner
State University of New York.
Plattsburg, New York

Mr. Emil J. Michal
El Paso Community College
El Paso, Texas

Elmer J. Phillippi
Muskingum Area Technical College
Zanesville, Ohio

Mr. John F. Ready
Honeywell Corporate Research Center
Bloomington, Minnesota

Mr. R. Sebek
St. Petersburg Junior College
Clearwater, Florida

Ms. Cynthia J. Teiss
PREP Inc
Trenton, New Jersey

Mr. John Webb
Wausau, Wisconsin

Dr. Jim Hahesy
Asnuntuck Community College
Enfield, Connecticut

Mr. Merton Jacobson
Anoka Area Vo-Tech Institute
Anoka, Minnesota

Mr. Lowell Jobe
Eastern Idaho Vo-Tech School
Idaho Falls, Idaho

Mr. Marcus C. King
Pitt Technical Institute
Greenville, North Carolina

Mr. Jim Lia Bratten
916 Area Vo-Tech Institute
White Bear Lake, Minnesota

Dr. Joseph F. Moran, Jr.
Cape Cod Community College
West Barnstable, Massachusetts

Mr. Tim Rush-Ossenbeck
Cincinnati Technical College
Cincinnati, Ohio

Mr. Larry Schmidt
Parkersburg Community College
Parkersburg, West Virginia

Dr. Elaine Stewart
Connecticut Community College System
Hartford, Connecticut

Dr. Russell K. Sigler
Miami-Dade Community College
Miami, Florida

Dr. Albert Seretny
Greater New Haven State Technical College
Hamden, Connecticut

Ms. Mary Smith
Department of Energy
Salem, Oregon

Dr. Paul D. Thompson
Daytona Beach Community College
Daytona, Florida

Mr. Bill Bennett
Colorado Northwestern Community College
Rangely, Colorado

Mr. Henry M. Berry
Trident Technical College
Charleston, South Carolina

Mr. Russell E. Clark
Tacoma Community College
Tacoma, Washington

Mr. Brice C. Custer
Trident Technical College
Charleston, South Carolina

Mr. Melvin F. Dostal
Marshalltown Community College
Marshalltown, Iowa

Mr. Leif Erickson
916 Vo-Tech Institute
White Bear Lake, Minnesota

Mr. James D. Hood
Horry-Georgetown Technical College
Conway, South Carolina

Mr. R. N. Jeanes
Greenville Technical College
Greenville, South Carolina

Mr. George A Rumsey
Miami-Dade Community College
Miami, Florida

Mr. Phil Callow
Albuquerque Technical-Vocational Institute
Albuquerque, New Mexico

Dr. Wilson W. Sorenson
Utah Technical College at Provo
Provo, Utah

Mr. Ashley J. Little
Aiken Technical College
Aiken, South Carolina

Mr. R. L. Grigsby, Jr.
Midlands Technical College
Columbia, South Carolina

Mr. Thomas B. Barton
Greenville Technical College
Greenville, South Carolina

Dr. Ed Dunn
Red Wing Area Vocational-Technical Institute
Red Wing, Minnesota

Dr. Otto R. Mauke
Camden County College
Blackwood, New Jersey

Dr. George Mehallis
Miami-Dade Community College
Miami, Florida

Dr. Charles A. Polk
Daytona Beach Community College
Daytona, Florida

Dr. Daniel McLaughlin
Asnuntuck Community College
Enfield, Connecticut

Mr. William F. Anderson
Horry-Georgetown Technical College
Conway, South Carolina

Mr. J. Robert Trevor
Maple Woods Community College
Kansas City, Missouri

Professor Roberto Algaze
University of Puerto Rico
Rio Piedras, Puerto Rico

Ms. Patricia Hartanowicz
Elizabeth Seton College
Yonkers, New York

J. E. Maffett
Pikes Peak Community College
Colorado Springs, Colorado

Charles King
New England Institute of Technology
Providence, Rhode Island

Mr. Marty Peterson
Harris Corporation
Quincy, Illinois

Richard W. Harris
Chattanooga State Technical Community College
Chattanooga, Tennessee

Dean C. J. Polonczyk
Bronx Community College
New York City, New York

Marshall Mock
Kauai Community College
Lihue, Hawaii

Joseph L. Hafer
Stark Technical College
Canton, Ohio

Dan Dell
Clermont
Batavia, Ohio

Dale C. Delano
Oklahoma State University Technical Institute
Oklahoma City, Oklahoma

Dr. Neal M. McBryde
Bee County College
Beeville, Texas

Wayne R. Michie
Virginia Western Community College
Roanoke, Virginia

Marcia R. Berasaid
Western Nevada Community College/South
Carson City, Nevada

J. J. Repetski
Niagara City Community College
Sanborn, New York

Gary Miller
Monroe Community College
Rochester, New York

Dean George Duncan
Suny Agri-Tech
Delhi, New York

M. A. Mann
Los Angeles Valley College
Van Nuys, California

John M. Barnard
Scott Community College
Bettendorf, Iowa

Ted Banitz
Cape Cod Community College
West Barnstable, Massachusetts

Edward Paul Mattar, III
Central New England College
Worcester, Massachusetts

Agnes Kemerer
Frederick Community College
Frederick, Maryland

Dr. Terry L. Cleveland
New Mexico Military Institute
Roswell, New Mexico

Robert O. Johnson
Franklin University
Columbus, Ohio

James M. Butterworth
West Hills College
Coalinga, California

Dr. Beryl McKinnciney
Ranger Junior College
Ranger, Texas

Dr. Don H. Hullman
Pratt Community College
Pratt, Kansas

D. N. Irwin
Southwestern Tech
Sylva, North Carolina

J. W. Gell
Iowa Western Community College
Council Bluffs, Iowa

Hubert H. Braun
Gateway Technical Institute
Kenosha, Wisconsin

Fred Langdon
Aiken Technical College
Aiken, South Carolina

Ron Johnston
Lon Morris College
Jacksonville, Texas

A. B. Sears
Albany Junior College
Albany, Georgia

Robert E. Klabenes
Southeast Community College
Milford, North Dakota

Leonard Welmer
Southern University
Shreveport, Louisiana

Joseph M. Zagroski
Mt. San Antonio College
Walnut, California

Frederick W. Lamb
Mott Community College
Flint, Michigan

Art Kincannon
Oscar Rose Junior College
Midwest City, Oklahoma

Ms. Mary Allen Jolley
Trident Technical College
Charleston, South Carolina

Robert O. Johnson
Franklin University
Columbus, Ohio

Bertram L. Blumenkrantz
North Shore Community College
Beverly, Massachusetts

Craig W. Smith
Paul Smiths College
Paul Smiths, New York

Dr. R. Horne
Chesapeake College
Wye Mills, Maryland

Dr. J. L. Hodges
University of Arkansas
Little Rock, Arkansas

Roger Conner
State Community College
East St. Louis, Illinois

Herb Nicholson
San Juan College
Farmington, New Mexico

Larry Eddy
Blue Mountain Community College
Pendleton, Oregon

Dr. John L. Bonte
Clinton Community College
Clinton, Iowa

Ms. Sue Honeycutt
The Northeast Mississippi Junior College
Booneville, Mississippi

Donald C. Wold
University of Arkansas
Little Rock, Arkansas

R. L. Mitchell
Hocking Technical College
Nelsonville, Ohio

Les Harris
Long Beach, California

Dr. William C. Warren
Southern Maine Vocational Technical Institute
South Portland, Maine

J. Louis Stokes
Utica Junior College
Utica, Mississippi

Andrew C. Kowalik
Garden City, New York

J. Keyzer
Anson Technical Institute
Ansonville, North Carolina

Charles R. Benson
Rowan Technical Institute
Salisburry, North Carolina

Marshall J. Piccin
Belmont Technical College
St. Clairsville, Ohio

Gordon Saam
Terra Technical College
Fremont, Ohio

Ward Balliston
Eastern Arizona College
Thatcher, Arizona

John P. Borris
St. Clair County Community College
Port Huron, Michigan

Joe Cunningham
Community College of Denver
Golden, Colorado

Walter Satre
Vermont Technical College
Randolph Center, Vermont

Frederick A. Voda
Worthington Community College
Worthington, Minnesota

Dr. Jim Cook
New Mexico State University
Alamagordo, New Mexico

Charles M. Woolf
Muskingum Area Technical College
Zanesville, Ohio

John Koch
Miles Community College
Miles City, Montana

Dr. J. A. Durham
Okaloosa-Walton Junior College
Niceville, Florida

Jack L. Foreman
Brazosport College
Lake Jackson, Texas

Victor Grob
Eastern Maine Vocational Technical Institute
Bangor, Maine

Dr. Martha T. Hatcher
Gainesville Junior College
Gainesville, Georgia

W. B. Mitchell
Ministerial Institute and College
West Point, Mississippi

Richard Conrad
Merced College
Merced, California

D. K. Harkcom
Anoka Ramsey Community College
Coon Rapids, Minnesota

Dr. Irene A. Petz
Palomar Community College
San Marcos, California

Richard McMullin
Dawson Community College
Glendive, Montana

Phillip N. Laughlin
San Joaquin Delta College
Stockton, California

Dr. D. Griffiths
University of Maine
Augusta, Maine

Paul R. Wignall
Brevard Community College
Cocoa, Florida

Michael Danehy
Suny Canton ATC
Canton, New York

Robert V. Crochunis
Harrisburg Area Community College
Harrisburg, Pennsylvania

Ruben Rivera
Metropolitan Institute of Science and Technology
Rio Piedras, Puerto Rico

S. Fabella
Cecil Community College
North East, Maryland

T. H. Vacha
Cuyahoga Community College
Parma Heights, Ohio

B. T. Anderson
Northlake College
Irving, Texas

W. M. Krummel
Westchester Community College
Valhalla, New York

Dr. T. Jean Mazero
Westmoreland County Community College
Youngwood, Pennsylvania

John H. McMillan
Mohawk Valley Community College
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Robert C. Nerbum
University of South Carolina
Sumter, South Carolina

Jack Banerdt
Gateway Technical institute
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Dean Jan R. Sonner
State Technical Institute of Knoxville
Knoxville, Tennessee

Eileen Hatcher
Houston Community College
Houston, Texas

Robert R. Hubbs
DeAnza College
Cupertino, California

Aaron Wenger
Rainy River Community College
International Falls, Minnesota

Bill Wells
Tulsa Junior College
Tulsa, Oklahoma

W. Von Glahn
Phymouth, Michigan

Don Kosterman
Paris Junior College
Paris, Texas

Lewis E. Aukes
Lincoln Trail College
Robinson, Illinois

R. E. Mandeville
NH Voc-Tech College
Manchester, New Hampshire

Orell R. Vanderwater
Lincoln Land Community College
Springfield, Illinois

C. Penny
Thornton Community College
South Holland, Illinois

Dr. Walters
Williamsport Community College
Williamsport, Pennsylvania

Richard M. Marsh
Chattanooga State Technical Community College
Chattanooga, Tennessee

Durward R. Huffman
Nashville State Technical Institute
Nashville, Tennessee

Joe Thomas
El Centro College
Dallas, Texas

Dr. E. Dee Martin
Utah Technical College
Provo, Utah

James R. Schnirel
Utah Technical College
Salt Lake City, Utah

Elaine D. Miller
Edmonds Community College
Lynwood, Washington

Karen Harding
Ft. Steilacoom Community College
Tacoma, Washington

Dr. Cyril O. Byron
Community College/Harbor Campus
Baltimore, Maryland

Frank Truesdale
Bunker Hill Community College
Charlestown, Massachusetts

Charles E. Hill
Rochester Community College
Rochester, Minnesota

Sherwood W. Peacock
Sampson Technical Institute
Clinton, North Carolina

Barbara A. Rousseau
NHCOC-Tech College
Nashua, New Hampshire

Samuel E. Tillis
Salem Community College
Penns Grove, New Jersey

Leonard G. Schofield
Cumberland Community College
Vineland, New Jersey

Alex Beattie
Modesto Junior College
Modesto, California

Kenneth B. White
Feather River College
Quincy, California

David Buckley
Polk Community College
Winter Haven, Florida

Robert M. Van Raes
Moraine Valley Community College
Palos Hills, Illinois

Gayle W. Wright
Parkland College
Champaign, Illinois

Thomas Reckerd
Indiana Vocational Technical College
Fayette, Indiana

Dr. James Hales
Fairmont State College
Fairmont, West Virginia

Dr. John F. Houlihan
Penn State University
Sharon, Pennsylvania

T. J. Perry
Marion Technical College
Marion, Ohio

M. Sperstad
Industry Education Center
Phoenix, Arizona

Larry Elder
Hartnell College
Salinas, California

Stanley H. Chin
Los Medanos College
Pittsburg, California

John C. Miller
Phillips College
Gulfport, Mississippi

Dr. L. Pepino
Gulf Technical Institute
Jamestown, North Carolina

Leonard Slominski
Lakeland Community College
Mentor, Ohio

Charles Danner
KSU Campuses, Stark Campus
Canton, Ohio

Fred F. Bartok
CCAC - Boyce Campus
Monroeville, Pennsylvania

Art Monroe
Mountain Empire Community College
Big Stone Gap, Virginia

Dr. Joseph F. Testa
Essex Community College
Baltimore County, Maryland

J. D. Ross
Northwest Mississippi Junior College
Senatobia, Mississippi

Leo R. Crisman
Umpqua Community College
Roseburg, Oregon

Robert Arbuckle
Penn State University
New Kensington, Pennsylvania

Hie M. Ball
University of Pittsburgh
Titusville, Pennsylvania

Darrell G. Smith
District 1 Technical Institute
Eau Claire, Wisconsin

Charles E. Jahren
Austin Community College
Austin, Minnesota

William G. Welch
Western Wisconsin Technical Institute
LaCrosse, Wisconsin

Edward W. Bilderbuck
The Moberly Junior College
Moberly, Missouri

Dr. Earl L. Matthews
Northwest Technical College
Archbold, Ohio

William O'Mahoney
Bloomfield Hills, Michigan

Glen Schrock
Hawkeye Institute of Technology
Waterloo, Iowa

UTC Usage

Over the past two and one-half years, the following organizations have implemented physics courses, using a total of 9,371 copies of UTC modules.

Arkansas Power and Light Company
Little Rock, Arkansas

Camden County College
Blackwood, New Jersey

Colorado Northwestern Community College
Rangely, Colorado

Greenville Technical College
Greenville, South Carolina

Horry-Georgetown Technical College
Conway, South Carolina

Marshalltown Community College
Marshalltown, Iowa

Miami-Dade Community College
Miami, Florida

North Central Technical Institute
Wausau, Wisconsin

Northern New Mexico Community College
Los Alamos, New Mexico

Red Wing Area Vocational Technical Institute
Red Wing, Minnesota

Southwest Virginia Community College
Richlands, Virginia

Tacoma Community College
Tacoma, Washington

Texas State Technical Institute
Amarillo, Texas

Texas State Technical Institute
Harlingen, Texas

University of California
Los Alamos Scientific Laboratory
Los Alamos, New Mexico

Utah Technical College at Provo
Provo, Utah

SUMMARY AND CONCLUSIONS

The proposal and statement of work for the UTC - Phase II project were prepared and submitted nine months before the grant was awarded. At that early point in time, UTC had been demonstrated as a very effective method of teaching practical physics; pilot testing of UTC - Phase I modules had only begun, and a complete evaluation of the development work was premature. The apparent need at that point in time was to develop more modules for making UTC relevant to other occupational education programs in skills development so that the usefulness of UTC to a school would be more comprehensive. The ensuing nine months progress on UTC - Phase I and the research in the first three months of UTC - Phase II revealed that a significant change in project emphasis was appropriate to assure maximum usefulness of the products of the grant activities.

The results of pilot testing on UTC - Phase I materials revealed a need for 1) significant revisions to the existing modules, 2) additional modules to complete the physics requirements for the engineering technologies, and 3) major revisions to the UTC program structure. Without these changes and additions, the highly appropriate and relevant course designs and delivery system for unified physics, developed in the first phase of this research effort, would receive very low usage in schools.

Research activities in the early months of UTC - Phase II project determined that the expansion of the use of UTC into other (industrial) technologies and skill training curricula was not feasible because the programs required only limited (and very specific) physics topics. A broad based, interdisciplinary delivery system for physics required more instructional time than was available and, in many areas, lacked the job relevance that is the vital motivator in these types of training programs.

The need for a change in the grant program emphasis was apparent. The idea to extend the usefulness of UTC to industrial technologies and skills training programs was dropped. Instead, research and development actitities

were concentrated upon improving the UTC structure, revising the existing modules, and adding new ones only to increase the UTC scope in engineering-related technologies. The combined efforts of UTC-I and UTC-II produced fewer modules than originally planned (191 instead of 250), but the scope has been proven adequate and the quality of the modules, as well as the effectiveness of the revised system, has been tested and demonstrated to successfully meet the original project objectives - i.e., a relevant delivery system of applied physics to provide a broad technical base for the technician.

Dissemination activities were extensive, and the results of these efforts have borne fruit - 15 schools using 9,371 copies of UTC modules in the past two years. And those figures should double this next year.

RECOMMENDATIONS

1. The objective of providing a broad, interdisciplinary base for today's modern technicians is counter to the philosophy of traditional specialized training provided in most technical institutes; consequently, the universal and rapid acceptance of UTC will not occur spontaneously. Dissemination activities should be sponsored to provide additional visibility to these materials and concepts, and workshops must be offered periodically to assist teachers and planners in implementing effective courses and programs.
2. The demonstrated (LASL pilot test on employed technicians) correlation between student competencies in algebra and learning achievement in UTC physics is additional evidence to the importance of well planned and executed math education. The two-tiered modular system developed in UTC (concept and application modules) appears to have useful application to a relevant delivery system in mathematics with math labs. Research should be conducted to determine the feasibility of such a system.
3. The UTC system and modules are sufficiently developed and revised to where they could now be subjected to a vigorous, quantitative field test. Sites are available and control groups could be established.

4. The continued availability and mechanism for correcting and updating the modules should be assured.
5. The use of the present UTC system in secondary schools should be investigated.
6. Research and development activities should be conducted to determine the usefulness of a unified physics concept for undergraduate baccalaureate programs in both technical and nontechnical areas.

APPENDIX A

MODULE DESCRIPTIONS

SUPPLEMENTARY MODULES

S1, FORMULA INTERPRETATION

This module discusses mathematics as the language of physics and presents formulas as mathematical models used to explain and to predict events in the physical universe. Basic algebraic techniques used to solve equations with a single unknown are presented with formulas from other UTC modules as examples. Topics discussed include ratios, proportions, powers and roots, and problem-solving techniques. Expressions involving trigonometry, logarithms, and exponentials are covered in other modules. In the laboratory, the student will solve equations for indicated variables.

Prerequisites: One year of high school algebra.

S2, INTERNATIONAL SYSTEM OF UNITS

This module discusses the International System of Units. It includes explanations of base, supplementary, and derived units of the SI system. The proper use of prefixes and the proper notations for stating quantities in SI units are included. This module also discusses the units not in the SI system that may be used with SI units and the conversion from SI to English units. A pencil-and-paper laboratory exercise is provided to give the student practical experience in manipulating SI units.

Prerequisites: One year of high school algebra.

S3, LOGARITHMS AND EXPONENTS

This module discusses the use of logarithms and powers of ten in solving problems in physics. Topics presented include the writing of numbers using powers of ten, significant figures, mathematical operations on numbers using powers of ten, exponential and logarithmic notations, common and natural logarithms, the use of log tables, and methods of solving logarithmic and exponential equations. Pencil-and-paper exercises provide the student with practice in using the techniques discussed.

Prerequisites: One year of high school algebra.

S4, ANGLES AND TRIANGLES

This module introduces angles and their measurement to the extent necessary to understand their use in triangles of several different types. Similar triangles, right triangles, and the Pythagorean theorem are presented. Trigonometric ratios of sine, cosine, and tangent are discussed. Protractors, metric scales, and an optional electronic calculator are used in the laboratory.

Prerequisites: One year of high school algebra.

S5, VECTORS AND SCALARS

Scalars and vectors are examined in this module; they are distinguished carefully from each other. Different methods of examining them are outlined in detail. The laboratory exercise consists of the drawing and the resolving of vectors.

Prerequisites: One year of high school algebra.

S6, DIMENSIONAL ANALYSIS

In this support module, the method of handling units in calculations (dimensional analysis) is presented in order that the units will reinforce the physics principles and assist in the problem-solving process. The advantages of dimensional analysis are presented, along with some of the techniques for handling units in calculations, as well as four working examples. The laboratory involves calculations and conversions with dimensional analysis.

Prerequisites: One year of high school algebra.

S7, READING AND DRAWING GRAPHS

This module discusses the use of graphs in presenting data. Methods of reading graphs, calculating slopes, and determining areas under curves are included. Some typical applications of graphs are provided. Pencil-and-paper exercises provide the student with practice in interpreting and preparing graphs similar to those found in other UTC modules.

Prerequisites: One year of high school algebra.

S8, PRECISION, ACCURACY, AND MEASUREMENT

This module discusses distinction between counting and measuring and factors affecting the measuring process. Topics include standards of measurement, precision and accuracy, calculating and stating limits of errors, direct and indirect measurements, and random and systematic errors in measurement. The proper techniques of measuring length with linear, vernier, and micrometer instruments are included. These techniques are used in a laboratory exercise, in which students analyze precision and accuracy of length measurements.

Prerequisites: One year of high school algebra.

1-0 FORCE

This module discusses the concept of force and forcelike quantities as they apply to four energy systems — mechanical, fluidal, electrical, and thermal. The forcelike quantities as discussed are force, torque, pressure, voltage, and temperature difference.

- Force causes motion of an object in a translational mechanical system. This force serves as the model for all forcelike quantities.
- Torque causes rotation of an object in a rotational mechanical system. Torque is a forcelike quantity.
- Pressure causes a fluid to move in a fluidal system. Pressure is a forcelike quantity.
- Voltage causes electrical charge to move in an electrical system. Voltage is a forcelike quantity.
- Temperature difference causes heat energy to move in a thermal system. Temperature difference is a forcelike quantity.

The following laboratory demonstrations are included: (1) Sliding wood blocks demonstrate that forces in mechanics cause motion. (2) Rotational motion is illustrated with a torque wrench. (3) A manometer is used to demonstrate force in the fluidal system. (4) The thermal system is exhibited in the form of a metal rod heated at one end until heat is "observed" to flow toward the cool end, where wax is melted on the rod.

Prerequisites: One year of high school algebra.

1M1, GRAVITY

The relationship between gravitational force and acceleration of free-falling objects is discussed. In the laboratory, weight and mass of several objects are determined; use is made of balances and scales.

Prerequisites: 1-0.

1M2, ADDITION OF MECHANICAL FORCES

In this application module, mathematical and graphical explanations of concurrent coplanar forces are discussed. Various vector relationships are presented, including two at right angles, two not at right angles, two on the same line in the same and opposite direction, and the resultant of more than two forces. A laboratory procedure using a scale and a force table enables the student to solve a series of force problems and to calculate the magnitude and direction of resultants.

Prerequisites: 1-0.

1M3, ADDITION OF TORQUES

This application module, as an extension of 1M2, examines what happens when all forces do not act through a single point. Two conditions for equilibrium are given, and explanations are given when $\Sigma F \neq 0$ and $\Sigma \tau \neq 0$. In the laboratory, the student will determine the mass of an object from the forces applied to it, and will determine the position required to balance it, or bring it to equilibrium.

Prerequisites: 1-0, 1M2.

1M4, MECHANICAL EQUILIBRIUM IN STRUCTURES

The applications of load-distribution examples are described. Trusses, gates, and crane booms are used as illustrations of force distribution and torque-absorbing members. Practical examples found in everyday situations are provided and solved. A procedure involving nine cases of a simulated crane boom system enables the student to measure and to calculate loads and angles.

Prerequisites: 1-0, 1M2, 1M3.

1M5, STRESS AND STRAIN

In this application module, a detailed look at stress and strain is made by examining Hooke's law, elasticity, deflection, shear modulus, twist, and bulk modulus. Experiments are provided to illustrate these aspects of stress and strain. Definitions of stress, strain, Hooke's law, elastic limit, yield point, breaking point, modulus of elasticity, shear modulus, bulk modulus, safety factor, and ultimate breaking strength are given. Procedures whereby the student measures Hooke's law values for brass, copper, aluminum, ultimate tensile strength for brass, copper, and aluminum wire, and deflections of a wooden beam are included.

Prerequisites: 1-0, 1M2.

1M6, TENSION IN WIRES AND CABLES

Tension and its general characteristics and applications are examined. The tension in weighted flexible lines also is presented in the discussion section and is the subject of the laboratory experiment.

Prerequisites: 1-0, 1M2.

1F1, ATMOSPHERIC PRESSURE

In this application module air-pressure magnitude and measurements is described by use of manometers and mercury and aneroid barometers. Boyle's law apparatus is used to demonstrate through experiments the effects of air pressure. A table of various units for standard pressure and four worked examples are included. Procedures enable the student to construct a mercury barometer and to measure and calculate pressure and volume of confined air (Boyle's law).

Prerequisites: 1-0.

1F2, DENSITY, BUOYANCY, AND SPECIFIC GRAVITY

This module introduces the methods of determining the density and specific gravity of fluids by means of floating objects placed within those fluids. Such suspended objects are acted upon by the downward force of gravity (weight) and by the upward buoyant force of the fluid. Specific gravity is applied in determining the amount of antifreeze in radiators, the amount of acid in batteries, etc. In the laboratory, the student will use a hydrometer to determine the specific gravity of several fluids.

Prerequisites: 1-0.

1F3, HYDRAULIC JACK

The hydraulic jack is an example of a force magnifier in a closed hydraulic system employing Pascal's law. By use of valves, a fluid reservoir, and pressure, large loads can be moved short distances with relative ease. Calculation of the input/output pressures are illustrated. The laboratory demonstrates this principle by use of disposable syringes.

Prerequisites: 1-0.

1F4, MANOMETERS

This module, basic to many later modules describes three types of manometers: U-tube, well, and inclined tube. The student will be introduced to the basic concepts of pressure measurement with manometers. Measurement of positive pressure, vacuum and differential pressure is illustrated. Industrial variations — the well-type manometer and the inclined manometer — also are presented. In the laboratory, the student will use a U-tube manometer to verify the calibration of a pressure gage.

Prerequisites: 1-0.

1E1, POTENTIAL DIFFERENCE AND CHARGE FLOW

This module discusses the origin of magnetic forces, the representation of magnetic forces in terms of magnetic fields, and the mapping of magnetic fields around bar magnets, horseshoe magnets, iron-core solenoids and long, straight wires. It also discusses how forces develop on current-carrying conductors in the presence of a magnetic field and how this principle is used in the construction of generators and motors. In the laboratory, the student will map magnetic fields, observe the results of forces upon current-carrying conductors in magnetic fields, and will construct and operate a simple electromagnet.

Prerequisites: 1-0.

1E2, SERIES AND PARALLEL VOLTAGE SOURCES

In this application module, the calculation and determination of emf's in linear and parallel circuits that have like and unlike poles connected are described. Examples of motor voltage calculation also are shown. Laboratory procedures enable the student to connect several different circuits and to measure voltages with a VOM across designated components.

Prerequisites: 1-0, 1E1.

1E3, ELECTRIC FORCES AND FIELDS

This module discusses magnetic forces between permanent magnetic and the magnetic forces affecting moving charges. The concepts of lines of magnetic force and magnetic fields are introduced and illustrated with permanent magnets and electromagnets. The relationship between charge, voltage, and capacitance also is presented. In the laboratory, the student will produce and describe line patterns of electric fields.

Prerequisites: 1-0.

1E4, MAGNETIC FORCES AND FIELDS

This module discusses the electric forces on charge particles due to a potential difference, lines of electric force, and the concept of the electric field as the ratio of change in potential to change in position. Examples include forces between like and unlike charges, electric fields produced by point charges, and electric fields in parallel-plate capacitors. The laboratory procedure allows the student to observe electrical forces, and a simple electromagnet is constructed and operated.

Prerequisites: 1-0, 1E3.

1E5, LEAD-ACID STORAGE BATTERY

The basic mechanisms of producing electrical energy in an acid battery are described. An automotive battery is examined in detail including the effect of changing to specific gravity and temperature and resulting electric potential output. Students are asked to construct, charge, and discharge a lead-acid storage cell.

Prerequisites: 1-0.

1T1, THERMOMETERS

The four temperature scales (Fahrenheit, Centigrade, Kelvin and Rankin) are compared, and conversion equations are provided. Also included are four temperature-sensing devices, including a thermocouple, gas thermometer, pyrometer, and liquid-in-glass types. Procedures enable the students to calibrate their own thermometer and to convert °F to °C.

Prerequisites: 1-0.

1T2, TEMPERATURE DIFFERENCE AND HEAT FLOW

In this application module, heat transmission by conduction, convection, and radiation is described. The movement of heat in an attempt to achieve thermal equilibrium also is discussed. Conduction experiments and methods of calculating conductivity of certain situations provide actual examples of the principles discussed. A laboratory procedure enables the student to measure the conductive properties of a portion of conducting material.

Prerequisites: 1-0.

1T3, THERMAL STRESS

In this application module, the mathematical and practical relationship of thermal expansion is expressed and described. A table of linear coefficients of expansion of several materials is provided. A procedure that demonstrates thermal expansion of a steel wire is included.

Prerequisites: 1-0.

2-0 WORK

Work is done in any physical system whenever a forcelike quantity causes a change (displacement-like quantity) within the system. Energy is the ability to do work, and is conserved within a closed system. When a system is in equilibrium, it contains energy, but no work is being done, because no displacement is occurring as the result of forcelike quantities within the system. When a system is not in equilibrium, displacement of some kind occurs as the result of forcelike quantities; and energy is converted to work within the system. Work and energy are equivalent and are measured in the same units.

Laboratory Demonstrations: (1) Work in the mechanical system is demonstrated by an object of known mass lifted a given distance. (2) Rotational work of a spinning gyroscope is analyzed. (3) A container is filled with fluid, and the work performed is determined. (4) Thermal and electrical work are demonstrated by a storage battery whose leads are connected through a small wire that generates heat in the water in which it is immersed.

Prerequisites: 1-0.

2M1, WORK DONE ON AN ELEVATOR

In this module, the mechanical work required to lift objects against the force of gravity is defined, and the inclined plane and its advantages in lifting are discussed. In the laboratory, the student will determine the work required to lift objects vertically and on an incline.

Prerequisites: 2-0.

2M2, WORK DONE BY A WINCH

This module presents an application of the concept of work in rotational systems, and describes in particular the rotational work into and out of a winch. Other topics discussed include the efficiency of winches, the use of geared winches and the effects of torque variations upon them. In the laboratory, the student will determine the work and efficiency of a winch.

Prerequisites: 2-0.

2F1, WORK DONE BY A WATER PUMP

In this module, the student will review principles of work and energy as they apply to fluids and electricity. Values for work and energy involving fluids and electricity will be derived experimentally and in problems. In the laboratory, the student will measure current and voltage supplied to a pump, and will calculate the work and efficiency of the pump.
Prerequisites: 2-0.

2F2, WORK DONE BY A HYDRAULIC LIFT

In this application module, a hydraulic lift is described with principles of industrial applications. Formulae are presented for input and output work in terms of mechanical, electrical, and pneumatic systems. A laboratory procedure enables the student to measure work through the use of a hydraulic jack.
Prerequisites: 2-0.

2T1, HEAT ENERGY REQUIRED FOR A TEMPERATURE INCREASE

This module introduces the use of the calorimeter for measurement of the thermal properties of materials. In the laboratory, the student will use a calorimeter (or experimental apparatus similar to a calorimeter) to measure some thermal properties of materials.
Prerequisites: 2-0.

2T2, HEAT ENERGY REQUIRED FOR MELTING

In this application module, examination is made of the energy requirements necessary to cause a change from solid to liquid state (heat of fusion). A table of melting points and heats of fusion of common solids and liquids is included. Working examples are provided. A procedure whereby the student can measure and calculate the heat of fusion is provided.
Prerequisites: 2-0.

2T3, HEAT ENERGY REQUIRED FOR BOILING

In this application module, the temperature of heated water as a function of time is measured, and the effect of heat of vaporization noted. Procedures for measurement of temperature-versus-time during boiling water and the cooling effect of an evaporating liquid are given for student completion.
Prerequisites: 2-0, 2T1.

2T4, FUNDAMENTALS OF AIR CONDITIONING

This application module includes definitions of heat-energy terms. A complete description of air conditioning principles and a schematic of a home air conditioner are provided. Energy Efficiency Ratios (EER's) are described and several common values included. An example of the cost comparison of several EER's is given. A laboratory procedure covering costs and efficiency of actual air conditioners is provided.
Prerequisites: 2-0.

3-0 RATE

This module presents the concept of rate as it applies to mechanical, fluidal, electrical, and thermal systems. In every case, rate expresses the ratio of a displacementlike quantity to an elapsed time:

- In a linear mechanical system, velocity is the ratio of distance traveled to elapsed time.
- In a rotational mechanical system, angular velocity is the ratio of angle of rotation to elapsed time.
- In a fluidal system, volume flow rate is the ratio of volume of fluid moved to elapsed time.
- In an electrical system, current is the ratio of charge transferred to elapsed time.
- In a thermal system, heat flow rate is the ratio of thermal energy transferred to elapsed time.

Laboratory Demonstrations: (1) Rate for mechanical systems is illustrated by a toy car, for which velocity and wheel speed are calculated. (2) For the fluid system, a water faucet is utilized to simulate discharge from a cooling system. (3) A conductometer is used to determine the rate of heat conduction for several materials. (4) Electric current is measured with an ammeter to determine rate of "flow."
Prerequisites: 2-0.

3M1, GRAPHICAL APPROACH TO LINEAR MOTION

The general subject of relationships between speed, position and time is called kinematics. In this module, only the description of motion along a straight line will be studied. Such motion is called rectilinear motion. A later module will concern present circular motion, which is somewhat more complicated. In the laboratory, the motion of an automobile is analyzed.
Prerequisites: 3-0.

3M2, VELOCITY AT CONSTANT ACCELERATION

This module provides problems that involve velocity and acceleration (constant acceleration) only to conform to the mathematical capabilities of the student. Working examples that cover acceleration, final speed, and time to reach a given speed are provided. A procedure in which the student measures the velocity of an object on a slope and straightaway track is given.
Prerequisites: 3-0.

3M3, DISPLACEMENT AT CONSTANT ACCELERATION

In this module, the student will learn that, given any three of the five motion parameters (displacement, initial velocity, final velocity, acceleration and time), the remaining two can be found. In the laboratory, the student will determine an acceleration down an incline and along a straightaway.
Prerequisites: 3-0, 3M2.

3M4, ACCELERATION OF A MASS BY CONSTANT FORCE

This module describes the relationship of force, mass, and acceleration; and it includes a discussion of displacement, initial velocity, final velocity, and time as parameters of motion. Construction of an Atwood's machine, a device used to determine the mass or acceleration of an object, also is discussed. In the laboratory, the student will use a pulley and other simple materials to construct an Atwood's machine and will determine the mass and acceleration of an object.
Prerequisites: 3-0, 3M2, 3M3.

3M5, ROTATIONAL MOTION

In this module, rotational motion is presented as the motion of a body that turns about an axis. Equations are presented that describe the relationship of angular displacement, angular velocity, and angular acceleration. In the laboratory, the student will use the equations and principles of rotational motion to determine the angular velocity and angular acceleration of a phonograph turntable.
Prerequisites: 3-0, 3M3.

3M6, RADIAL ACCELERATION AND CENTRIPETAL FORCE

Centripetal force is the inward force upon an object as it moves in a circular path. Radial, or centripetal, acceleration of an object is the change in its velocity divided by a time interval. Radial acceleration, centripetal force, and centrifugal force are discussed in this module, and the operation of governors and centrifugal pumps is examined. In the laboratory, the student will use a centripetal force apparatus to determine the radial acceleration and centripetal force of a rotating object.
Prerequisites: 3-0, 3M5.

3F1, FLOW RATE MEASUREMENT WITH A VENTURI METER

This module presents operating principles of a venturi flow meter, a typical device used in industry for accurate flow-rate measurements. An experiment is included to give the student hands-on experience in the use of a laboratory model of a venturi tube.
Prerequisites: 3-0.

3E1, ELECTRIC CURRENT

The concepts of direct and alternating current are examined. The laboratory exercise acquaints the student with important current measurements with a d.c. ammeter and with an a.c. ammeter.
Prerequisites: 3-0.

3E2, FREQUENCY

Frequency and time relate to each other in repetitive events. The importance of known frequencies for time measurement is noted, as well as the concept of spatial frequency. In the laboratory, the student will measure electrical frequencies with an oscilloscope; will measure the period of a pendulum; and will use a laser in determining the spatial frequency of the grooves in a diffraction grating.
Prerequisites: 3-0.

3T1, HEATING AND COOLING RATE

This module presents the rate of heating and cooling as change in temperature divided by time. Examples of the calculation of cooling/heating rates are presented, and a graphical presentation is made. A procedure provides the student with the capability of measuring and plotting heating rate.

Prerequisites: 3-0.

3T2, RATE OF HEAT CONDUCTION

This module treats the rate of heat conduction through solid materials, taking into account the physical quantities affecting rate, and relating them through a coefficient of thermal conductivity or an average coefficient of heat transmission. The use of insulation in reducing the rate of heat conduction is emphasized. In the laboratory, the student will determine the rate of heat conduction for several materials.

Prerequisites: 3-0.

4-0 MOMENTUM

Moving objects possess a very important physical quantity called "momentum." "Linear momentum," a vector quantity, depends upon the mass and the linear velocity of the object. "Angular momentum," also a vector quantity, depends upon the moment of inertia and the angular velocity of a rotating mass. This module explains the mathematical relationships involved with both linear and angular momentum. Elastic and inelastic collisions are considered, as well as "the law of conservation of momentum."

Laboratory Demonstrations: (1) Linear momentum is demonstrated by use of an air tract or by dry-ice pucks. (2) Angular momentum of a rotating platform or stool is observed. (3) Elastic and inelastic collisions are exhibited by a number of spheres (each of a different material) dropped on a steel base.

Prerequisites: 3-0.

4M1, ANGULAR MOMENTUM OF A FLYWHEEL

An examination of several rotating systems and their calculation is presented. A table of the analog between translational and rotational quantities is given, as well as several examples for the calculation of the angular momentum of discs. A procedure for the experimental calculation of flywheel-type device is provided.

Prerequisites: 4-0.

4M2, IMPULSE AND MOMENTUM

Impulse is the product of force and the duration of application of the force. An impulse applied to a mass causes a change in momentum of the mass. This module discusses impulse and change in momentum as it applies to mechanical components and systems of modern technology. In the laboratory, the student will measure impluse and change in momentum.

Prerequisites: 4-0.

4M3, CONSERVATION OF MOMENTUM IN COLLISIONS

In this module, momentum conservation is applied to elastic and inelastic collisions. In the laboratory, the student will analyze both elastic and inelastic collisions in one dimension to verify conservation of momentum. An air track and two air carts are employed in the laboratory.

Prerequisites: 4-0.

4M4, GYROSCOPES

In this module, the student will learn how the properties of the gyroscope depend upon torque and angular momentum. The student will solve problems involving these parameters and gain an understanding of the vector nature of the gyroscopic effect. In the laboratory, the student will observe the effects of external forces on a spinning gyroscope. The student will also use the gyroscopic effect to determine the angular momentum of a spinning gyroscope. Finally, the student will construct a simple gyrocompass.

Prerequisites: 4-0, 1M3, 1M4.

4F1, ROCKET ENGINES

The general characteristics of rocket propulsion are discussed, and the concepts of momentum and impulse are applied to the performance of rocket engines. An experiment provides a hands-on test of the impulse produced by ignition of a solid-fuel model rocket engine.

Prerequisites: 4-0.

5-0 RESISTANCE

This module discusses (1) the phenomenon referred to in a general way as "resistance" and (2) the application of the concept of resistance to mechanical, fluidal, electrical, and thermal systems. The discussion includes the similarities of resistance in all energy systems. These similarities make resistance a unifying concept. The discussion also includes the differences in resistance characteristics from one system to another.

Laboratory Demonstrations: (1) Dry friction of an object pulled across a dry surface is determined. (2) Friction of free-falling balls in glass tubes filled with different fluids is calculated. (3) Flow resistance of a pipe from a tank is calculated. (4) Electrical resistance of a resistor is determined by use of a milliammeter and a voltmeter.

Prerequisites: 3-0.

5M1, STATIC AND SLIDING FRICTION

Resistance occurs in all energy systems. This module examines friction, the resistance in a mechanical energy system. Lubricating oils are used in automobile engines specifically to reduce friction between moving parts. At other times, it is more important to increase friction. Lining materials in automobile brakes, for example, are carefully selected to increase the friction between moving parts. In the laboratory, (1) a sliding friction block is shown to exhibit force of static and kinetic friction; and (2) friction blocks are slid on an angled surface to determine coefficient of static friction at various angles of repose.

Prerequisites: 5-0.

5M2, EFFECT OF LUBRICANTS

This module explains how lubricants overcome or reduce friction. It also lists some of the basic properties of lubricants. In the laboratory, metal blocks of various materials are slid on an aluminum plate with and without lubricants. The coefficient of static and kinetic friction is calculated for each test.

Prerequisites: 5-0.

5M3, ROLLING FRICTION

Rolling friction (the resistance to rolling movement in a mechanical system) is not as great as other friction (the resistance of sliding friction). Ball and roller bearings — both of which exhibit rolling friction in movement — have little rotational resistance. The efficiency of a mechanical system is increased when components that exhibit high sliding friction are replaced with those that exhibit rolling friction. In the laboratory, the coefficient of rolling friction is determined for a bowling ball on carpet and for a weighted bicycle wheel.

Prerequisites: 5-0.

5F1, LAMINAR AND TURBULENT FLOW

This module discusses laminar and turbulent flow and presents the Reynolds number as a ratio that describes flow quality. In the laboratory, the student will use a venturi tube, a manometer, and a needle valve to investigate laminar and turbulent flow of fluids that have different viscosities.

Prerequisites: 5-0, 3F1.

5F2, VISCOSITY

The viscosity of a liquid can be described as internal resistance to motion of the liquid. It is the primary source of resistance when a liquid flows through a pipe, when an object moves through a liquid, or when two surfaces separated by a lubricant move relative to each other. In this module the effects of viscosity in lubrication systems are presented. Methods of measuring viscosity and the effect of temperature on viscosity of lubricants also will be discussed. In the laboratory, the student will use a fashioned rolling sphere viscometer to measure the viscosity of several lubricating oils at varying temperatures.

Prerequisites: 5-0.

5F3, FLUID RESISTANCE IN PIPES

There are many causes for energy losses in any system that uses fluid power. The major cause of energy loss in a fluid-power system is friction produced when the fluid molecules bump against one another and against the pipe walls. Friction produced in this manner is manifested as heat given off to the surrounding air or to some cooling media. Heat always represents a loss of energy in a fluid-power system. In the laboratory, the student will investigate how the friction losses in a pipe are affected when the pipe's length or diameter is changed and when the viscosity of the fluid that flows through it is changed.

Prerequisites: 5-0.

5F4, VALVES AND REGULATORS

Valves are devices used to control the flow of fluids and gases. Regulators, more correctly identified as "pressure regulators," are devices that maintain a constant output pressure at different flow rates. This module discusses valves and regulators as variable fluid resistors. In the laboratory, the student will use a cylinder of nitrogen gas and a flowmeter to measure the resistance of valves and regulators.

Prerequisites: 5-0, 5F3.

5F5, SHOCK ABSORBERS

A shock absorber is a mechanical device that provides resistance in a mechanical system. In most applications, this resistance is applied to reduce mechanical oscillations. In this module, the principles of operation and the construction details of several shock absorbers are presented. In the laboratory, the student will measure resistance of an automobile shock absorber when a force is applied to it in both the compression and decompression modes.

Prerequisites: 5-0.

5F6, DRAG-RESISTANCE TO MOTION THROUGH FLUIDS

When an object moves through a fluid, or when a fluid moves around an object, a force acts to impede the motion. In this module, the properties of this fluid drag force and calculations of its magnitude are presented. Calculations for the terminal velocity of an object moving through a fluid are discussed. In the laboratory, the student will construct a device with which to measure the drag force exerted on a sphere by a regulated stream of gas and will calculate the sphere's drag resistance.

Prerequisites: 5-0, 5F1, 5F2.

5E1, OHM'S LAW

George Ohm's contribution to the mastery of electricity began with experiments concerning the relationship of the potential difference, or voltage, between the ends of a metallic conductor and the current flowing through it. What resulted is one of the most important tools for working with electricity and electronics available today. In honor of the discoverer, this tool is called "Ohm's law." This module introduces Ohm's law and its relationship to voltage, current, and resistance. In the laboratory, the student will measure and calculate these three qualities in single-resistor circuits. A d.c. power supply and a Volt-ohm-milliammeter will be used.

Prerequisites: 5-0, 3E1.

5E2, SERIES AND PARALLEL RESISTORS

Resistances connected in series form a single pathway for current flow; resistances connected in parallel form branches, each of which provides a separate path for current flow. Each type of resistance circuit has its own characteristics and uses.

Measurements and calculations often are necessary to determine if a circuit is operating as it should. In the laboratory, the student will use light bulbs as sources of resistance in place of the usual resistors, in order that the effect of series and parallel resistance circuits upon electrical current flow can be observed more directly.

Prerequisites: 5-0, 5E1.

5E3, INTERNAL RESISTANCE OF A BATTERY

Electrical applications of the resistance concept are familiar, but resistance of the power source in a circuit often is neglected, as it usually is a small value compared with the other elements in the system. In this module, applications in which the total circuit resistance is low enough to cause internal resistance of the battery to become significant are considered. In the laboratory, internal resistance of a lantern battery is calculated from measurements taken by a voltmeter through assorted resistors.

Prerequisites: 5-0.

5E4, CONDUCTORS, SEMICONDUCTORS AND INSULATORS

Whether a material is a conductor, an insulator, or a semiconductor depends upon its ability to conduct an electrical current. The conductor possesses low resistance to current flow; the insulator, high resistance; and the semiconductor, high resistance when at low temperature and low resistance at high temperature. This module examines the electrical properties of conductors, insulators, and semiconductors. In the laboratory, the student will use a VOM to determine the resistance of several material samples and will compare their characteristics.
Prerequisites: 5-0, 5E1.

5E5, RESISTANCE OF WIRES

The degree of resistance of a wire depends upon its composition, length, cross-sectional area, and temperature. A wire possessing good conductance has low resistance. A wire having strong resistance will rise in temperature and in resistance when current is increased through it. This module presents the factors affecting the resistance of wires. In the laboratory, the student will use an ammeter to determine the resistance of wires at different temperatures.
Prerequisites: 5-0, 5E1.

5E6, RESISTANCE OF SEMICONDUCTOR JUNCTIONS

Conventional resistors are "fixed" in value (except for temperature changes); therefore, their control of current flow in a circuit also is fixed. Some circuit applications, however, call for a device that has variable control over circuit current, meaning that the resistance of the device must be variable. This module examines the properties of the semiconductor P-N junction diode. The NPN transistor is analyzed to demonstrate how resistance of the output circuit is varied, or controlled, by input bias voltage. In the laboratory, the student will use a milliammeter, a micro-amp meter, and a voltmeter to measure the resistances of several diodes and transistors.
Prerequisites: 5-0, 5E1.

5E7, RESISTANCE OF GAS LASER TUBES

In this module, the electrical characteristics of the gas laser are presented. The negative resistance of the gas discharge tube is explained, and the principles of defining the general requirements for a gas-laser power supply are discussed. In the laboratory, the student will use a microammeter and a voltmeter to measure the electrical properties of a neon gas discharge tube.
Prerequisites: 5-0, 5E1.

5E8, VOLT-OHM MILLIAMMETER

Module 5-0, "Resistance," discusses the relationship of voltage, current, and resistance known as Ohm's Law. A volt-ohm-milliammeter (VOM) is a device used to measure all three of these electrical quantities. It is one of the most versatile and commonly-used test instruments in technical fields related to electrical and electronic circuits. This module deals with the basic elements of the meter and its measurement of the most common electrical quantities. Proper use and precautions to be taken with the instrument also are discussed. In the laboratory, the student will use a volt-ohm-milliammeter to measure voltage, current and resistance.
Prerequisites: 5-0.

5T1, THERMAL CONDUCTIVITY

The ability of a substance to transmit heat by conduction is a physical property of the particular materials and is characterized by its "thermal conductivity." This module investigates the heat flow rate of several materials and examines how heat flow rate varies with material, thermal conductivity, and material thickness. In the laboratory, the student will use oven thermometers, heat lamps, and a hot plate to investigate the effects of thermal conductivity and material thickness on heat flow rate.
Prerequisites: 5-0.

5T2, HEAT FLOW THROUGH INSULATION

Insulation slows down (impedes, resists) flow of heat in the same manner that a resistor impedes flow of electrical current. Increased insulation can reduce greatly the heat losses in a structure and thereby substantially reduce heating and cooling costs. In the laboratory, the student will use heat lamps and oven thermometers to determine the thermal resistance of several commercial insulating materials.
Prerequisites: 5-0, 3T2.

6-0 POWER

The concept of power has useful meaning in many energy systems. In this module, the idea of power is applied to common problems in electrical, fluid, mechanical rotational, and mechanical translational systems. Power is the rate of energy consumption and in a given energy system is the product of the forcelike quantity and rate appropriate to that system.

Laboratory Demonstrations: (1) The power developed by a person in running up stairs is calculated. (2) Calculation is made for power required to raise a weight attached by string to a rotating dowel. (3) Another experiment requires power calculations, at both input and output, of a combined electrical-fluid system (a pump); an ammeter and a voltmeter are used for measurements.
Prerequisites: 5-0.

6M1, HORSEPOWER

The origin and use of the term "horsepower" are investigated and four worked examples involving horsepower are provided. In the laboratory, the student will measure the power of an electric motor or winch in terms of its horsepower and will determine the horsepower of an automobile from its weight and acceleration.
Prerequisites: 6-0, 3M2, 3M3.

6M2, PRONY BRAKE

The prony brake is a device used to determine the operating characteristics, such as horsepower, of motors, engines, and turbines. Manufacturers often check the hp of power sources with the prony brake to ensure that the tested output power is equal to that specified. In the laboratory, the student will use a prony brake to measure speed and torque characteristics of an electric motor, will prepare a graph of speed versus torque, and will prepare a graph of motor efficiency versus torque.
Prerequisites: 6-0.

6F1, HYDRAULIC POWER

This module discusses the applications, advantages, and disadvantages of hydraulic power. Hydraulic power is produced when an incompressible fluid is pressurized by hydraulic pumps and is piped to hydraulic cylinders or motors for conversion into mechanical energy and power. In the laboratory, the student will determine the horsepower produced by a water pump sending fluid through a hydraulic system.
Prerequisites: 6-0.

6E1, ELECTRICAL POWER MEASUREMENT

Electrical power is measured to determine kWh usage and cost. In this module, the concept of electric power is reviewed, power usage is defined, and equipment for measuring watts and watthours is described. In the laboratory, the student will examine a kilowatt hour meter, use the meter to measure the power consumed by various electric appliances, and calculate an electric bill according to a typical rate structure.
Prerequisites: 6-0, 5E1.

6E2, ELECTRIC HEATER

This module presents the electric heater as an example of a purely resistive load. Calculations are provided for the determination of a heater's power consumption and its conversion of electrical energy to heat energy. In the laboratory, the student will use a voltmeter and an ammeter to determine the power consumed by an electric heater and its conversion of electrical energy to heat.
Prerequisites: 6-0.

6E3, EFFICIENCY OF ELECTRIC MOTORS AND GENERATORS

This module describes the efficiency of energy conversion in motors and generators as a ratio of output power to input power. Factors contributing to power losses and reduction of efficiency are discussed. In the laboratory, the student will use a wattmeter and a prony brake to determine the efficiency of an electric motor.
Prerequisites: 6-0.

6E4, ELECTRICAL POWER CONSUMPTION

Home appliances use varying amounts of electrical power and add varying contributions to the monthly electric bill. This module examines the relative levels of electrical power consumption for some common appliances, and discusses their costs of operation. In the laboratory, the student will measure the electrical power consumption of some appliances with a wattmeter and a kilowatt-hour meter, and will determine relative costs of operations.

Prerequisites: 6-0, 6E1.

6T1, HEAT EXCHANGERS

In this module, a heat exchanger is presented as a device that moves thermal power from one part of a thermal system to another. Solid-to-air, liquid-to-air, liquid-to-liquid, and refrigeration system exchange are described. Two working examples of power calculations are provided. In the laboratory, the student will calculate power exchange of an automobile radiator used as a heat exchanger. Equipment used includes a pump, a portable fan and a wattmeter.

Prerequisites: 6-0, 2T1.

7-0 POTENTIAL AND KINETIC ENERGY

Energy itself is a fundamental unifying concept, because it is common to all systems. In all systems we notice that whenever work is done, there is an increase in kinetic or in potential energy, or in both. When energy is transformed from one system to another, we expect the total amount of energy present to remain the same, including heat energy produced by friction. If friction is present, a portion of the work is represented by a frictional heat energy loss. In the absence of friction, the sum total of the kinetic and potential energy remains constant, although there may be exchanges between these two forms of energy. This fact, known as the "conservation of energy," is one of the fundamental principles upon which all science and technology are based.

Laboratory Demonstrations: (1) Objects first at rest and then in rolling down an inclined track demonstrate potential energy at rest and kinetic energy in motion. (2) The exit velocity of fluid through holes in pails will be determined in two ways. (3) Mechanical energy necessary to rotate a small electric generator to charge a capacitor will be found.

Prerequisites: 6-0.

7M1, PILEDRIVER

Forging hammers and piledrivers convert gravitational potential energy to kinetic energy. In this module, the piledriver as an energy storage and delivery device is investigated. In the laboratory, the student will construct a piledriver and will investigate the effects of changes in the mass and height of the piledriver blow.

Prerequisites: 7-0, 3M3.

7M2, POTENTIAL ENERGY OF A SPRING

The stretching or compressing of a spring stores mechanical energy in the spring. This energy can be recovered as useful work by allowing the force present in the spring to cause motion toward the equilibrium position of the spring. This module discusses the forces acting upon a spring and the storage of energy in it. In the laboratory, the student will determine a spring constant and will calculate the period of a spring-mass system.

Prerequisites: 7-0.

7M3, ROTATIONAL KINETIC ENERGY OF A FLYWHEEL

A turning flywheel possesses kinetic energy in the form of the mechanical, rotational energy of its mass. This rotational kinetic energy, stored as potential energy, can be converted to other forms for use at a later time. This module provides examples of different inertia flywheels and a description of the use of a flywheel as an aid in transportation. In the laboratory, the student will construct a simple flywheel from a wheel and axle and will determine its energy-storage efficiency.

Prerequisites: 7-0.

7M4, CONSERVATION OF ENERGY IN COLLISIONS

This module discusses the conservation of momentum and kinetic energy in collisions. The ballistic pendulum is described as a device that measures the kinetic energy and momentum of a projectile in a totally inelastic collision. In the laboratory, the student will use a ballistic pendulum to determine the conservation of energy in a collision.

Prerequisites: 4-0, 7-0, 4M3.

7M5, KINETIC ENERGY AND HORSEPOWER OF AN AUTOMOBILE

In the automobile engine, chemical energy in the fuel is converted by combustion into heat energy and, in turn, into mechanical energy. Engine horsepower is the rate at which the engine can develop energy for work in propelling the automobile. This module presents a discussion of automobile engine horsepower and its measurement. In the laboratory, the student will weigh an automobile and time its acceleration on a drag strip to determine the horsepower of the engine.

Prerequisites: 3-0, 6-0, 7-0.

7F1, ENERGY STORED IN LARGE TANKS

This module presents the development of Torricelli's theorem from Bernoulli's equation. The energy exchanges that occur in the steady flow of an incompressible, viscous fluid are presented, and an application of Torricelli's theorem to the energy stored in large tanks is included. In the laboratory, the student will use an aspirator bottle or a container with a hole near the bottom to demonstrate Torricelli's theorem.

Prerequisites: 7-0.

7F2, VENTURI METERS

A venturi meter is a device used in industry for flow rate measurements. This module presents the application of Bernoulli's equation to a venturi meter and the derivation of an equation that determines flow velocity in a horizontal pipe. A discussion of potential and kinetic energy changes for fluid flowing through a horizontal pipe is included. In the laboratory, the student will use a triple-arm manometer and a venturi meter to determine velocity of flow.

Prerequisites: 7-0.

7F3, PITOT TUBES

This module presents the operating principles of the pitot tube, its advantages and limitations in fluid velocity measurement, and its various features of construction. The pitot tube equation for velocity flow is derived from Bernoulli's equation. In the laboratory, the student will use a pitot tube to measure the air speed of a moving automobile.

Prerequisites: 7-0.

7F4, ENERGY CONVERSION IN FLUID SYSTEMS

This application module demonstrates the conversion of potential energy (capacity to do work by virtue of position) into kinetic energy (capacity to do work by virtue of motion) in a fluid system. In the laboratory, the student will use a water motor equipped with a prony brake to determine the energy in a fluid system.

Prerequisites: 7-0.

7F5, GAS LAWS

Gases possess kinetic energy in the form of moving molecules that collide with each other and with objects in which they are contained. These collisions cause pressure that increases as the temperature increases. This module illustrates the solutions of many problems related to gases and introduces laws formulated to explain the behavior of gases. In the laboratory, the student will use a manometer to investigate Gay-Lussac's law and Boyle's law.

Prerequisites: 7-0, 1F1, 1F4.

7F6, SIPHONS

In this module, the physical principles that produce flow in a siphon are explained. The relationship between atmospheric pressure, liquid pressure, elevation, liquid velocity, and fluid resistance in a siphon are illustrated by the application of Bernoulli's equation. In the laboratory, the student will use containers and tubing to illustrate the relationship between fluid elevation, flow in the siphon, and fluid resistance in the siphon.

Prerequisites: 7-0, 1F1.

7E1, ENERGY STORED IN A BATTERY

This module describes the battery as a chemical energy storage device. Energy required to charge the battery is compared to energy available at discharge, and work done by the battery at various times of its discharge is discussed. In the laboratory, the student will use an ammeter and a voltmeter to measure the charging and discharging of a battery.

Prerequisites: 7-0.

7E2, ENERGY STORED IN A CAPACITOR

This module presents capacitors as devices that store electrical potential energy. Basic capacitor designs are discussed and a circuit for charging a capacitor is shown. Energy stored in a capacitor and voltage required to charge a capacitor are calculated. In the laboratory, the student will use an oscilloscope to trace the discharge of a capacitor and will calculate stored capacitor energy from his measurements.
Prerequisites: 7-0.

7E3, ENERGY STORED IN AN INDUCTOR

Magnetic potential energy is stored in the magnetic field of an inductor. In this module, air-core and iron-core inductors are contrasted, and the reaction of an inductor to changing currents is discussed in terms of the energy stored in its magnetic field. In the laboratory, the student will use an ammeter to measure the current through an automobile ignition coil and will calculate the energy stored in its magnetic field.
Prerequisites: 7-0.

7E4, SERIES AND PARALLEL CAPACITORS

This module examines the properties of circuits that include capacitors connected in series or in parallel. The concept of the potential energy of equivalent capacitance is introduced, and its practical applications are discussed. In the laboratory, the student will use a voltmeter to examine capacitors connected in series and in parallel and will determine an unknown capacitance.
Prerequisites: 7-0, 7E2.

7T1, HEAT STORAGE SYSTEMS

This module investigates the way in which various materials store heat. The heat pump is described as a mechanical device that transfers heat from one medium to another, and examples of the use of heat pumps are provided. In the laboratory, the student will compare the heat storage capacity of various materials.
Prerequisites: 7-0.

7T2, ELECTRICAL EQUIVALENT OF HEAT

In this module, the conversion of electrical potential energy to heat energy is presented. Calculations of electrical energy and heat energy are demonstrated, and their relationship is discussed. In the laboratory, the student will use a voltmeter, an ammeter, and a thermometer to investigate the conversion of electrical energy to heat.
Prerequisites: 7-0.

7T3, MECHANICAL EQUIVALENT OF HEAT

This module describes the conversion of mechanical energy to heat energy and includes examples of temperature increase in auto brakes, a waterfall, and a falling weight. In the laboratory, the student will measure the increase in temperature of falling lead balls and will calculate the mechanical equivalent of heat.
Prerequisites: 7-0.

7T4, THERMAL DRYING

In this module, the concept of kinetic energy of atoms and molecules is applied to an explanation of thermal drying of moist materials. The thermal nature of drying is explored in a discussion of molecular behavior of water vapor in accordance with the kinetic molecular theory. Evaporation of moisture from a moisture-containing solid is discussed as an important mechanism of drying. General characteristics of several types of industrial thermal dryers are presented. In the laboratory, the student will use a triple beam balance and a source of drying heat to determine the moisture content of an apple and a piece of freshly cut wood.
Prerequisites: 7-0.

7T5, MIXING LIQUIDS AT DIFFERENT TEMPERATURES

Substances possess internal kinetic energy in the form of the microscopic motion of their molecules. When liquids at different temperatures are mixed, molecular motion causes them to reach an equilibrium temperature. This module discusses the internal kinetic energy of liquids and several methods of determining specific heat and final temperature of substances mixed at different temperatures. In the laboratory, the student will construct a simple calorimeter to determine the specific heat of a liquid and the final temperature of a mixture.
Prerequisites: 7-0.

8-0 FORCE TRANSFORMERS

This module treats a class of devices called "force transformers" because, in such devices, the force output is different from the force input. However, the work, or energy output, is never greater than the work or energy, input; and with an ideal case in which no energy is lost to frictional forces, the work output equals the work input. Force transformers are simply machines having great diversity and having a wide variety of applications, but the basic explanation of their usefulness is the same. The unified approach taken in the preceding modules will assist in understanding force transformers in different energy systems as examples of the same physical principle.

Laboratory Demonstrations: (1) The mechanical advantage (M) of a lever is calculated. (2) The M of an inclined plane is found. (3) Efficiency of an electric transformer is calculated from measurements of voltage and current.

Prerequisites: 6-0.

8M1, LEVERS

In this module, the lever is presented as a force transformer. Three classes of levers are discussed, and examples and applications are presented. Equations for the calculation of actual and ideal mechanical advantage are included. In the laboratory, the student will measure and calculate the mechanical advantages of several levers.

Prerequisites: 8-0, 1M3.

8M2, WEDGES AND INCLINED PLANES

A wedge is a device that transforms a small force applied in one direction into a pair of larger opposing forces almost perpendicular to the original force. This module describes the wedge as a pair of inclined planes and provides calculations of the mechanical advantage and efficiency of a wedge. In the laboratory, the student will use spring scales to determine the mechanical advantage and efficiency of a wedge.

Prerequisites: 8-0, 1M2.

8M3, DRIVE SYSTEMS

Torque transformers called "drive systems" are employed when changes in torque and angular velocity are desired. In this module, gear systems, belt drives, and disk drives are presented as examples of torque transformers. In the laboratory, the student will examine the disk drive of a phonograph turntable.

Prerequisites: 8-0, 1M3.

8M4, GEAR TRAINS

This module discusses the design, characteristics, and applications of a variety of common gear-drive systems. Equations are presented for the calculation of the mechanical advantage, or gear ratio, of common and planetary gears. In the laboratory, the student will examine the gear train in the gear box of a machine shop lathe.

Prerequisites: 8-0, 8M3.

8M5, BLOCK AND TACKLE

This module presents the block and tackle as a pulley system that operates on the principle of lever action. Various pulley systems are discussed, and examples are provided for the calculation of mechanical advantage and efficiency. In the laboratory, the student will use a spring balance and weights to determine the mechanical advantage and efficiency of several pulley systems.

Prerequisites: 8-0.

8M6, DIFFERENTIAL HOIST

In this module, the wheel and axle are included in a block and tackle system in order to produce a differential hoist, or chain hoist. The differential hoist is described, and calculations for its mechanical advantage and efficiency are provided. In the laboratory, the student will use a spring balance and weights to determine the mechanical advantage and efficiency of a differential hoist.

Prerequisites: 8-0, 8M5.

8F1, HYDRAULIC PRESS

In this module, hydraulic force transformation, closed hydraulic systems, and mechanical advantages are presented. Pascal's law is reviewed, and practical applications to a hydraulic press are given. In the laboratory, the student will use disposable syringes, clear tubing, and weights to construct and operate a simulated hydraulic press.

Prerequisites: 8-0.

8E1, ELECTRICAL TRANSFORMERS

This module introduces the operating principles of the transformer. Voltage, current, power relationships, and transformer power losses are investigated. In the laboratory, the student will construct an electrical transformer and will use a voltmeter to measure voltage of the transformer. Calculated values of voltage will be compared to measured values.

Prerequisites: 8-0, 3E1.

9-0 ENERGY CONVERTORS

Our modern technological society depends upon the production, distribution, and consumption of large amounts of energy. These processes are made possible by a group of devices that can be classified as "energy convertors." These devices accept input energy in one energy system and deliver output energy in another system. Some of the input energy is lost, because energy convertors are not one-hundred percent efficient. This module discusses (1) a variety of energy convertors, important in the conversion and application of energy and (2) the efficiency of the individual energy convertors and systems.

Laboratory Demonstrations: (1) Efficiency of an electric water pump is determined for electrical and fluid systems. A wattmeter is employed. (2) Sunlight is converted into electrical energy by a photocell. Conversion efficiency is calculated from milliammeter measurements.

Prerequisites: 6-0.

9F1, TURBINES

In this module, the basic characteristics and operating principles of a turbine are presented. Energy transformations are traced diagrammatically for gas, steam, wind, and water turbines. In the laboratory, the student will use a prony brake to determine the efficiency of a small model water turbine.

Prerequisites: 9-0.

9F2, FLUID PUMPS

Fluid pumps convert mechanical energy into fluid energy. Fluid energy supplied by pumps is utilized either to circulate fluid or to pressurize it for use in hydraulic fluid motors or cylinders. This module discusses the principles, characteristics, and applications of the hydrodynamic pump and several types of positive displacement pumps. In the laboratory, the student will examine the characteristics of a hydrodynamic pump and will use a wattmeter to determine the power of the pump.

Prerequisites: 9-0, 6F1.

9F3, WIND POWER

Windpower is produced by machines that convert wind energy into mechanical energy, which can be used for a variety of purposes. In this module, power delivered by a windmill is discussed, and various wind-power devices and their characteristics are presented. In the laboratory, the student will use a simple wind generator to produce electricity and will use an anemometer, a voltmeter, and an ammeter to determine the conversion efficiency of wind energy into electrical energy.

Prerequisites: 9-0.

9F4, FANS AND BLOWERS

In a fan or blower, the electrical energy of the motor is converted into the rotational mechanical energy of the fan blades. The mechanical energy of the fan blades then moves the air through the discharge duct, thereby creating fluid energy. This module presents the theory of operation and basic design of fans and blowers. In the laboratory, the student will use a manometer to determine the air horsepower and the efficiency of a fan motor.

Prerequisites: 9-0.

9F5, VACUUM PUMPS

A number of different pumps are used to produce a vacuum in enclosed chambers. These pumps include rotary mechanical pumps, diffusion pumps, sputter-ion pumps, and cryogenic pumps. This module emphasizes the operation of the various types of pumps used to evacuate vacuum systems. In the laboratory, the student will use at least two different pump types to evacuate a vacuum system and will use vacuum gages to measure the pressure in the system during pump-down.
Prerequisites: 9-0, 10F5.

9E1, ELECTRIC GENERATORS

An electric generator converts rotational mechanical energy to electrical energy. This module presents the theory of operation and basic design of d.c. generators. In the laboratory, the student will operate a d.c. generator and will use a voltmeter and a milliammeter to determine the electrical power generated.
Prerequisites: 9-0, 1E4.

9E2, ALTERNATORS

In an electric generator, a voltage is produced in a conductor that moves through a magnetic field. In an alternator, the voltage is produced as the magnetic field moves through stationary coils. This module presents the theory, construction details, and applications of alternators. In the laboratory, the student will use an oscilloscope and a VOM to determine the output power and efficiency of an alternator.
Prerequisites: 9-0, 9E1.

9E3, ELECTRIC MOTORS

The electric motor converts electrical energy into mechanical rotational energy. Its operation is made possible by the magnetic field inside the motor and by the forces exerted by the field upon conductors passing through it. This module introduces the principles that govern the operation of direct current (d.c.) electric motors. In the laboratory, the student will use a horseshoe magnet and simple materials to build and operate a permanent-magnet motor and a series motor.
Prerequisites: 9-0, 1E4.

9E4, SOLENOIDS AND RELAYS

The solenoid converts electrical energy into mechanical energy. The relay contains a solenoid attached to a switch. This module discusses the operation and applications of the solenoid and the relay. In the laboratory, the student will identify relay terminals and will operate starter and electric motor control circuits.
Prerequisites: 9-0, 1E4.

9E5, PHOTOVOLTAIC MATERIALS

Photovoltaic materials are semiconductors; specifically, they are junctions between a P-type semiconductor and an N-type semiconductor. When light strikes these materials, electrical current is generated. This module examines the operation and construction of photovoltaic materials. In the laboratory, the student will use an optical power meter, a milliammeter, and a photovoltaic detector to measure efficiency of conversion of light energy into electrical energy. The light source is a Helium-neon laser.
Prerequisites: 9-0.

9T1, BOILERS

Boilers convert the thermal energy of burning fuel into the potential and kinetic energy of steam. This module discusses the energy conversion from hot combustion gases to pressurized steam in a boiler. In the laboratory, the student will determine the effects of preheated water and of ash deposits upon steam generation. A miniature steam engine is utilized.
Prerequisites: 9-0.

9T2, THERMOELECTRIC GENERATORS

This module explores thermoelectricity, the direct conversion of heat energy into electrical energy (or the reverse) by means of three related physical phenomena — the Seebeck effect, the Peltier effect, and the Thomson effect. Thermoelectric effects are exhibited by both metallic conductors and by semiconductors. In the laboratory, the student will use a potentiometer to measure the voltage generated by thermocouple wires and thermoelectric semiconductors, and will investigate cooling produced by a thermoelectric cooler.
Prerequisites: 9-0.

9T3, SOLAR COLLECTORS

This module discusses solar collectors, which convert the energy of light radiation into thermal energy or into electrical energy. Flat-plate and concentrating (focused) collectors produce thermal energy in the fluid circulating through them; whereas, photovoltaic collectors convert light radiation directly into electrical energy. In the laboratory, the student will construct a small section of a flat-plate collector and measure its efficiency, and will use a voltmeter and an ammeter to measure the conversion efficiency of a silicon photovoltaic collector.
Prerequisites: 9-0.

10-0 TRANSDUCERS

Transducers are devices that accept an input signal containing information in one energy system (engine temperature, for example) and convert it into an output signal containing the same information in another energy system (displacement of a needle on a calibrated gage scale). This module discusses transducers commonly used to transform information about mechanical, fluidal, electrical, thermal, and optical systems into an electrical or mechanical signal.

Laboratory Demonstrations: (1) A thermocouple transducer is utilized to measure water temperature. (2) Electrical energy of a horn is converted into acoustic energy through a microphone connected to an oscilloscope. (3) A turbine flowmeter is employed as a transducer to measure water flow.
Prerequisites: 9-0.

10M1, STRAIN GAGES

The strain gage is a transducer device used in the measurement of dimensional stress changes in a surface. This module introduces the construction and operation of various strain gages. In the laboratory, the student will use a Wheatstone Bridge (commercial or improvised) and a spring scale to measure the change in resistance of a wire subjected to strain, and will use a strain gage to measure strain.
Prerequisites: 10-0.

10M2, ACCELEROMETERS

In this module the piezoelectric accelerometer is presented as a device based on the principle that certain crystals exhibit surface charges when subjected to mechanical stress. Since the magnitude of the charge is proportional to the stress, these devices can be used to measure acceleration. Two types of accelerometers are described, and a working example for the calculation of acceleration is provided. In the laboratory, the student will use an accelerometer and an oscilloscope to measure a variety of accelerations.
Prerequisites: 10-0.

10F1, BOURDON TUBES

The bourdon tube is a mechanical transducer whose pressure element transforms fluid energy or motion into detectable pressure changes on a readout device. This module discusses the design and operation of the bourdon tube and describes the bellows and the diaphragm pressure transducers. In the laboratory, the student will use a regulated air pressure source, a pressure gage, and a manometer to operate and calibrate a bourdon tube.
Prerequisites: 10-0.

10F2, ANEROID BAROMETERS

An aneroid barometer is an energy transformer that accepts input energy from the pressure of a gas surrounding it and transforms it into potential energy in a spring. A pointer, or other display device, indicates the amount of energy stored in the spring. In this module, the construction and applications of an aneroid barometer are investigated. In the laboratory, the student will measure a variety of pressures with an aneroid barometer and will express each pressure in several standard pressure units.
Prerequisites: 10-0, 1F2.

10F3, DIFFERENTIAL-PRESSURE TRANSDUCERS

Differential-pressure tranducers are used when a pressure measurement involves reference to two different pressure levels. This module describes differential-pressure transducers and illustrates their use in level measurement and fluid flow measurement. In the laboratory, the student will use a regulated air supply and a manometer to investigate the operation of a differential-pressure transducer.
Prerequisites: 10-0.

10F4, FLUID-FLOW MEASURING DEVICES

This module describes the measurement of fluid flow by an orifice plate and manometer system and by a magnetic flowmeter. In the laboratory, the student will measure flow with a plate type orifice meter and with a turbine meter. Equipment used includes a pump, a mercury manometer, and a voltmeter.
Prerequisites: 10-0, 7F2.

10F5, VACUUM GAGES

This module examines a variety of different gages used to measure vacuum. Units for the measurement of pressure are discussed, and mechanical diaphragm, mercury manometers, McLeod, thermocouple, Pirani, and hot cathode ionization gages are examined. In the laboratory, the student will use a mechanical pump and valve to investigate the operation of various vacuum gages.
Prerequisites: 10-0, 9F5.

10E1, METER MOVEMENTS

Meter movements are energy transducers that change part of the energy of a magnetic field into mechanical potential energy stored in a coiled spring. A pointer attached to the coil indicates the value of the current flowing through the coil. This module presents the operation and application of meter movements. In the laboratory, the student will use a commercial VOM and a meter movement to construct a voltmeter and an ammeter.
Prerequisites: 10-0, 1E3, 1E4.

10T1, AUTOMOBILE THERMOSTATS

This module presents the automobile thermostat as a device that employs the principle of thermal expansion to control the temperature of the automobile engine. As the water in the engine block is heated, thermal expansion in the thermostatic device opens a valve that allows the water to flow to the radiator. In the laboratory, the student will examine the operation of an automobile thermostat.
Prerequisites: 10-0.

10T2, BIMETALLIC STRIPS

This module discusses bimetallic strips, which are constructed of two metals that have different coefficients of linear expansion. When the strip is heated, differential expansion causes it to bend in proportion to the change in temperature. Uses of bimetallic strips as thermostats and thermometers are discussed. In the laboratory, the student will construct a bimetallic strip, measure its deflection when heated, and use a bimetallic strip to construct a control circuit.
Prerequisites: 10-0.

10T3, TEMPERATURE MEASURING DEVICES

This module presents four methods of temperature measurement: (1) fluid thermal systems (2) bimetallic strip (3) thermocouple and thermopile, and (4) thermistor. In the laboratory, the student will use a mercury thermometer, a VOM, a thermocouple, and a thermistor to measure temperature.
Prerequisites: 10-0.

10T4, THERMOCOUPLES

A thermocouple produces a thermoelectric voltage that corresponds to a temperature difference across a junction of two dissimilar metals. This module presents the theory and practical applications of thermocouples. In the laboratory, the student will use a thermometer and a voltmeter to determine the thermoelectric voltage of different thermocouples.
Prerequisites: 10-0.

10T5, THERMISTORS

The thermistor is a semiconductor transducer device whose resistance varies considerably with temperature. The resistance of some thermistors increases with a temperature increase, while that of others decreases with the same temperature increase. This module explores the construction, operation, characteristics, and applications of thermistors. In the laboratory, the student will use a VOM and a thermometer to investigate the resistance and temperature characteristics of a thermistor.
Prerequisites: 10-0.

10T6, PYROMETERS

This module describes the pyrometer as a device that measures radiation emitted from a heated material. Included are equations for the calculation of temperature from radiant power and spectral emission. Tables of emissivity of several materials are presented. In the laboratory, the student will use a radiation pyrometer and an optical pyrometer to measure the temperature of heated materials.
Prerequisites: 10-0.

11-0 VIBRATIONS AND WAVES

A wave is a periodic disturbance in either a medium, such as air, or in a vacuum, such as space. Some waves require a medium; for example, sound waves require air through which to travel. Light waves and other electromagnetic waves do not require a medium. Wave energy can be transmitted in the form of a single pulse or in many evenly-spaced pulses. Wave velocity is affected by the material through which waves travel. Two or more waves are superimposed when they overlap within the same medium to produce standing waves or interference. Wave motion applies, as a unifying concept, to mechanical, fluidal, and electrical systems.

Laboratory Demonstrations: (1) A doorbell is situated inside a bell jar in which a vacuum is created by a vacuum pump. Sound level is determined for the bell inside and outside the jar. (2) The shapes of waves in a slinky are sketched. (3) Waves are superpositioned from two loudspeakers; a microphone picks up the sounds and transmits them to an oscilloscope that displays their characteristics.

Prerequisites: 6-0.

11M1, SPEED OF SOUND IN MATERIALS

Sound waves travel through various materials with a speed dependent upon the elastic properties of the materials, characterized for each material by a constant called the "modulus of elasticity." This module discusses the velocity of sound in different types of materials. In the laboratory, the student will use an oscilloscope and a microphone to determine the velocity of sound in different media.

Prerequisites: 11-0.

11M2, REFLECTION AND ABSORPTION OF SOUND ENERGY

This module discusses sound waves, echoes, and sound absorbent materials. Absorption and reflection coefficients, sound-level measurements, and exposure to noise are examined. In the laboratory, the student will use a sound level meter or a microphone and oscilloscope to determine sound levels transmitted through, and reflected from, various materials.

Prerequisites: 11-0.

11M3, VIBRATION ISOLATION

In this module, the characteristics of steady-state vibrations are illustrated, and the methods used to eliminate or reduce these vibrations in various kinds of machinery are discussed. Equations are provided for the isolation of external and internal vibrations. In the laboratory, the student will use an oscilloscope and an accelerometer to measure the acceleration of an electric motor and its support in order to determine transmission of vibration.

Prerequisites: 11-0.

11M4, RESONANCE

Many mechanical, electrical, and fluid systems have natural frequencies at which they oscillate easily. Resonance occurs whenever pulsating energy is delivered to these systems at their natural (resonant) frequency. This module discusses resonance and gives examples of conditions in which resonance is either an advantage or a disadvantage. In the laboratory, the student will describe the resonance of four pendulums and of waves produced by tuning forks in a resonance tube.

Prerequisites: 11-0, 11E1, 11F1.

11M5, SOUND SPEAKERS

A sound speaker is a device that converts electrical energy into sound energy. In this module, the design and performance of several types of speakers is examined. Emphasis is placed on construction details of speakers that produce high fidelity sound over specific frequency ranges. In the laboratory, the student will use an audio signal generator, a microphone, an audio amplifier, and an oscilloscope to determine the frequency response of a moving coil speaker.

Prerequisites: 11-0, 1E4.

11F1, CAVITY VIBRATIONS AND STANDING WAVES

Many devices require the formation of standing waves to be able to perform their functions. Standing waves are produced when two waves of equal amplitude and frequency interfere with each other while traveling in opposite directions. A "cavity" is a volume containing a medium that supports wave reflection at the ends of the volume. This module investigates standing waves and conditions necessary for their formation. In the laboratory, the student will produce acoustic standing waves in an "organ pipe" and determine characteristics of cavity vibrations. The laboratory will require the use of an oscilloscope, an audio signal generator, a speaker, a microphone, and two tubes.

Prerequisites: 11-0.

11F2, SPEAKER ENCLOSURES

This module discusses the characteristics of bass reflex, horn, and full speaker enclosures. In the laboratory, the student will measure directionality of sound produced by a speaker with and without an enclosure. Materials to be used include an audio signal generator, an oscilloscope, a speaker, a microphone, and an audio amplifier.

Prerequisites: 11-0, 11M5, 11E3.

11F3, REVERBERATION TIME

This module describes the reverberation time of sound waves as part of the study of acoustics. The basic principles of acoustics are discussed and an example of the calculation of reverberation time for a room is provided. In the laboratory, the student will measure the dimensions of the various surfaces in a room and will calculate the reverberation time of the room.

Prerequisites: 11-0.

11F4, DOPPLER EFFECT

The Doppler effect is the apparent change in the frequency of sound or of electromagnetic radiation due to relative motion between the source and the observer. This module examines the Doppler effect for both sound and electromagnetic waves and includes equations for the determination of frequency shifts associated with the effect. In the laboratory, the student will use a stroboscope, an oscilloscope, a microphone, and either a commercial or constructed Doppler's principle apparatus to investigate the Doppler effect of sound waves.

Prerequisites: 11-0, 11M1.

11F5, PRESSURE MEASUREMENT OF SOUND WAVES

Sound waves are small variations in pressure superimposed upon the normal atmospheric pressure. These small changes from atmospheric pressure are called "sound pressure." This module examines the elementary principles that characterize the production, transmission, and measurement of sound. In the laboratory, the student will use a sound level meter to measure sound-pressure levels and will draw the contours of equal sound-pressure levels around a sound source.

Prerequisites: 11-0.

11E1, ALTERNATING VOLTAGE AND CURRENT

When a voltage periodically changes with respect to time, it is referred to as an "alternating voltage." This alternating, wave-like voltage, when applied to a complete circuit, will cause an alternating current to flow. This module compares and contrasts a.c. and d.c. characteristics and describes the effects they produce in various circuit components, such as resistors, capacitors, and coils. In the laboratory, the student will use an oscilloscope, a signal generator, a voltmeter and an ammeter to measure peak-to-peak voltage and will compare resistance, inductive reactance, and capacitive reactance.

Prerequisites: 11-0.

11E2, PHASE RELATIONSHIPS IN a.c. CIRCUITS

Direct current encounters opposition from the resistance of conductors. Alternating current encounters both resistive opposition and opposition in the form of capacitive and inductive reactances. These reactances cause the current and voltage to be out of step with each other. This module investigates capacitive and inductive reactances, their measurements, and how they affect alternating-current circuits. In the laboratory, the student will use an ammeter and a voltmeter to determine the impedance, phase angle, and power factor of RC, RL and RLC circuits.

Prerequisites: 11-0.

11E3, OSCILLOSCOPE

The oscilloscope is one of the most important electrical devices available for measurement of electrical quantities. It is particularly useful in graphic representations of wave forms that may occur at high frequencies. This module explains the basic operation of a single-trace oscilloscope and a dual-trace oscilloscope, and it describes the use of Lissajous patterns for frequency determination. In the laboratory, the student will analyze oscilloscope sine waves, phase difference, and Lissajous patterns produced by signal generators.

Prerequisites: 11-0.

11E4, RECTIFIERS

The conversion of alternating current into direct current is necessary in many electronic circuits. A rectifier (diode) accomplishes this conversion. In this module, the principle of rectification is discussed, and the operation of a rectifier in an electrical circuit is examined. Rectification in fluid and mechanical systems also is discussed. In the laboratory, the student will assemble circuits containing rectifiers and will examine their performance with an oscilloscope.

Prerequisites: 11-0.

11E5, ELECTRONIC FILTERING IN d.c. POWER SUPPLIES

Electronic filters are used in d.c. power supplies to reduce the ripple of a.c. components at the load. Choice of the filter type to be used depends upon the ripple factor, regulation, and current of the power supply. This module discusses the construction, characteristics, and applications of several filter types. In the laboratory, the student will use electronic components, a multimeter, and an oscilloscope to construct and evaluate several filters.

Prerequisites: 11-0, 11E4.

11E6, ELECTRONIC FILTERING FOR FREQUENCY SELECTION

Electronic filtering for frequency selection is accomplished by means of reactive circuits. Reactive circuits are composed of capacitors and inductors that react to changes in the amplitude of a signal. Frequency dependence of capacitive and inductive reactance permits their use in filtering for frequency selection. This module examines high-pass, low-pass, selective, notch, band-pass, and band-stop filters. In the laboratory, the student will use a signal generator, an oscilloscope, and an ohmmeter to investigate the frequency selection of various filters.

Prerequisites: 11-0, 11E1, 11E2.

11E7, MODULATION OF ELECTRICAL WAVES

Information is transmitted through space in the form of varying electromagnetic waves. The process by which information is introduced onto a transmitted wave is called "modulation." This module discusses amplitude modulation (AM) and frequency modulation (FM), which are the two basic types of modulation used in modern communications. In the laboratory, the student will use an RF signal generator, an audio signal generator, and an oscilloscope to observe amplitude modulation of waves.

Prerequisites: 11-0.

12-0 TIME CONSTANTS

In many practical situations, it is important to know how swiftly a system will give up or accept energy, will change its temperature, or will return to equilibrium after some initial displacement. Time constants — intervals of time during which a system undergoes a change — are used to describe how fast systems are changing. If the time constant for a changing system is known, one can predict time required for the complete change to take place; for example, the time required for a capacitor to reach 99% of a fully-charged condition. In this module, time constants will be shown to be common to different energy systems and to serve, therefore, as a unifying concept.

Laboratory Demonstrations: (1) Time constants are determined for a weight attached to a flexible spring that is placed in motion. (2) A torsion pendulum flywheel is placed in motion on a shaft; the time required for it to reach a given amplitude of oscillation is calculated. (3) Water in a beaker is brought to a boil and allowed to cool to room temperature; the time constant for this process and for the thermometer used is calculated and plotted.

Prerequisites: 7-0 and a knowledge of exponential terms.

12M1, SHOCK ISOLATION BY ABSORBERS

Shock isolation in a mechanical system is accomplished by absorbers that damp mechanical oscillations transmitted from one portion of the system to another. This module examines the principles and applications of vibration isolation systems. In the laboratory, the student will use a piezoelectric accelerometer and an oscilloscope to observe vibration isolation in simple mechanical systems.
Prerequisites: 12-0, 10M2.

12F1, RATE OF EMPTYING TANKS

When large tanks are drained by gravity, the emptying process resembles the discharge of an electrical series resistance-capacitance combination and can be described by a time constant. This module describes the process of emptying a cylindrical tank and discusses the various parameters associated with the fluid flow from the tank. In the laboratory, the student will empty a large cylindrical container to demonstrate the fluid-system behavior described in the module.
Prerequisites: 12-0.

12E1, RC CIRCUITS

In electronic circuits, it often is necessary to provide some kind of timing signal to synchronize events. One of the most common sources of such a signal is a resistance-capacitance (RC) circuit. This circuit generates regularly-spaced pulses by charging and discharging a capacitor through a resistor. This module examines the characteristics of RC timing circuits and the time constant. In the laboratory, the student will construct an RC timing circuit and test it with an oscilloscope.
Prerequisites: 12-0.

12E2, RL CIRCUITS

An RL series circuit consists of resistance R in series with an inductor of self-inductance L. To distinguish between the effects of resistance and self-inductance, the RL circuit analyzed in this module consists of an ideal, resistanceless inductor in series with a separate noninductive resistor. An example of a real inductor with resistance is included. In the laboratory, the student will use an oscilloscope, a signal generator, and a VOM to determine the exponential behavior of current and voltage, and will measure the time constant associated with their decay.
Prerequisites: 12-0, 11E2, 7E3.

12E3, RLC CIRCUITS

This module examines the characteristics and applications of resistance-inductance-capacitance (RLC) circuits. Examples of RLC circuit problems are presented, and an equation for the calculation of energy stored in a capacitor is included. In the laboratory, the student will use an oscilloscope, a VOM, and several circuit components to observe the pulse shapes of overdamped, underdamped, and critically damped RLC circuits.
Prerequisites: 12-0, 12E1.

12T1, RESPONSE TIME OF THERMOCOUPLES

This module discusses heat in situations in which temperature is changing rapidly. Under these conditions, response time of a temperature-measuring device becomes important. Response time of a thermocouple depends upon its size, its material, and its bonding to the material under study. In the laboratory, the student will use an oscilloscope and liquid nitrogen or ice-water to determine response times for a conventional thermocouple and a thin-film thermocouple, and will use a thermocouple attached to a strip chart recorder to measure thermal diffuseness of a sample of metal.
Prerequisites: 12-0.

12T2, TIME CONSTANTS OF HEATING AND COOLING

Time constants associated with the response of temperature-measuring devices are important factors to consider in the design of an accurate temperature-measuring system. This module describes time constants for heating and cooling and relates the time constants to the rate of temperature changes of a body as it heats or cools. In the laboratory, the student will use thermometers and insulated containers to determine how different surface characteristics of a hot body affect the time constant and the rate at which it cools.
Prerequisites: 12-0.

13-0 RADIATION

Radiation is the process by which energy moves away from a source in a straight line. Sound waves, light waves, and alpha and beta rays are examples of radiation. Although these examples represent three distinct classes of radiation, each example moves energy radially away from some source, and all have common characteristics.

This module addresses mainly the topic of electromagnetic (EM) radiation — sometimes called "radiant energy." In this type of radiation, energy is transmitted by variations in electric and magnetic fields. Radiant energy includes gamma rays, x-rays, ultraviolet, visible, infrared, microwaves, radar, television, and radio waves. It is the basis of modern communication, of solar energy, and of sight itself.

Laboratory Demonstrations: (1) The laws of reflection and refraction are demonstrated with a He-Ne laser. (2) Polarized EM radiation is emitted by a microwave transmitter through a grid analyzer to a receiver. (3) The inverse-square law is demonstrated by use of a light bulb and a light meter.
Prerequisites: 11-0, 1E3, 1E4.

13L1, INVERSE SQUARE LAW — SPREADING OF LIGHT

This module presents the inverse-square law, which describes the rate of decrease in irradiance of light as the distance from its source increases. The concepts of solid angle, radiant intensity, and irradiance are explained and calculated in examples. In the laboratory, the student will use an incandescent bulb and an optical power meter to measure irradiance as a function of distance from a light source.
Prerequisites: 13-0.

13L2, THE OPTICAL SPECTRUM

This module presents the characteristics and applications of light within the optical spectrum, which includes the infrared, visible, and ultraviolet portions of electromagnetic spectrum. Common wavelength units and the origin of continuous, band, and line spectra are discussed. Equations for calculating the frequency and energy of a photon are presented and used in examples. In the laboratory, the student will use a grating spectroscope to measure the wavelength of visible light from various sources, and will calculate the frequency and energy of photons.
Prerequisites: 13-0.

13L3, LIGHT SOURCES

In this module, the process by which light is produced in incandescent, fluorescent, and metal vapor light sources is presented. The discussion includes characteristics of point and extended sources of light. In the laboratory, the student will use an optical power meter and a grating spectroscope to observe the irradiance pattern and output spectra of incandescent and fluorescent sources.
Prerequisites: 13-0, 13L1, 13L2.

13L4, LASERS

The laser is a source of unique light radiation and has a wide variety of applications. Laser light is used to drill holes in diamonds, to weld steel accurately, to measure large distances, and to repair detached retinas. This module discusses the properties of laser light, the basic theory of operation of the laser, and a number of important laser applications. In the laboratory, the student will learn how to operate a low-power, helium-neon laser.
Prerequisites: 13-0.

13L5, STROBOSCOPES — PULSES OF LIGHT

In this module, the stroboscope is presented as a device that produces short pulses of light. The major parts of a stroboscope and of an automobile engine timing light are described. In the laboratory, the student will use a stroboscope to measure the rotational rate of a fan and to observe water drop formation and will utilize an automobile timing light (strobe-light) to check the timing of an automobile engine.
Prerequisites: 13-0.

13L6, OPTICAL FILTERS — ABSORPTION OF LIGHT

This module presents the absorption of light by atoms, the exponential law of absorption, and the transmission curves for several types of optical filters. The absorption coefficient of a filter material is defined and used in examples. In the laboratory, the student will use a laser and an optical power meter to derive curves of transmission versus filter thickness and to calculate the absorption coefficient of optical filters.
Prerequisites: 13-0, S3, 13L2, 13L3.

13L7, SPECULAR AND DIFFUSE REFLECTION OF LIGHT

This module discusses the law of reflection as it applies to specular and diffuse reflectors. Absorption, scattering, reflection, and transmission at optical surfaces are presented. Applications of partial and total reflectors are discussed. In the laboratory, the student will use a helium-neon laser and a power meter to compare the characteristics of diffuse and specular reflections.

Prerequisites: 13-0, 13L4.

13L8, IMAGE FORMATION WITH MIRRORS

This module presents the formation of images by mirrors. Ray diagrams are included to illustrate the formation of virtual and real images by plane and spherical mirrors. Equations for determining image location and size are provided, and applications of several optical arrangements employing mirrors are presented. In the laboratory, the student will use a concave mirror to construct a solar furnace and to create real and virtual images.

Prerequisites: 13-0, 13L7.

13L9, PRISMS — REFRACTION AND DISPERSION OF LIGHT

Reduction of the speed of light as it passes through a prism is responsible for light refraction (bending) and for light dispersion (spreading of colors). This module presents refraction of light at plane surfaces and a discussion of variations in the angle of refraction for different colors of light. In the laboratory, the student will use a prism spectrometer to measure light velocity and index of refraction of a prism at several wavelengths of light.

Prerequisites: 13-0, 13L2.

13L10, LENSES — FOCUSING AND SPREADING OF LIGHT

Lenses are optical devices that change the directionality of light beams by refracting different parts of the beams by differing amounts. This module discusses properties of lenses, formation of real and virtual images by lenses, and a variety of lens applications. In the laboratory, the student will use lenses to construct a small refracting telescope.

Prerequisites: 13-0, 13L9.

13L11, INTERFERENCE — TESTING FLAT SURFACES

This module describes interference as the way in which light waves interact. If two light waves are in phase at a point on a screen, a bright spot is produced. If the two waves are completely out of phase, a dark area results. The alternating light and dark fringes of such an interference pattern can provide useful information about the surface dimensions of an object. In the laboratory, the student will use a mercury vapor lamp, an optical flat, and a positive lens to investigate interference patterns.

Prerequisites: 13-0, 13L1, 13L7.

13L12, DIFFRACTION GRATING — MEASURING THE WAVELENGTHS OF LIGHT

This module discusses Huygens' principle and the diffraction of light at edges and slits. Equations are presented for the calculation of wavelength, diffraction angle, and grating spacing. In the laboratory, the student will use a grating spectroscope to measure the wavelength produced by a helium spectrum tube.

Prerequisites: 13-0, 13L2, 13L9, 13L11.

13L13, POLARIZATION — GLARE REDUCTION

The polarization of light is a description of the orientation of its electric field in space. This module discusses characteristics of polarized light and methods of producing and measuring polarization of light. The origin of glare and its reduction by polarizing optical components also is presented. In the laboratory, the student will use a helium-neon laser, an optical power meter, and two linear polarizers to investigate the polarization of coherent light.

Prerequisites: 13-0, 13L4.

13L14, HOLOGRAPHY — THREE DIMENSIONAL PHOTOGRAPHY

Holography is a method of using coherent laser light to record and reproduce three-dimensional images. This module discusses the differences between holography and ordinary photography, techniques used in making and viewing holographic images, and several applications of holography. In the laboratory, the student will use a helium-neon laser, a diverging lens, and a hologram to observe the three-dimensional image produced by holography.

Prerequisites: 13-0, 13L4, 13L12.

13L15, SPECTROSCOPY – LIGHT ANALYSIS

Spectroscopy is an analysis of light emitted by, reflected from, or transmitted through a material and may be used to determine a variety of things about the material. This module discusses several types of optical instruments used in spectroscopy and presents a wide variety of applications of spectroscopy in science and industry. In the laboratory, the student will use a spectrophotometer to determine the transmission curve of a didymium filter.

Prerequisites: 13-0, 13L2, 13L6, 13L8, 13L11, 13L12.

13L16, INFRARED RADIATION THERMOMETERS

This module discusses the way in which the infrared radiation emitted from most objects can be used to determine the object's temperature. The design and limitations of a simple infrared radiation thermometer are presented. In the laboratory, the student will make practical measurements with an infrared radiation thermometer.

Prerequisites: 13-0, 13L2.

13L17, ILLUMINATION

This module examines different quantities associated with the measurement of radiant energy. The efficiency and spectral composition of various light sources are presented. The principles of operation and practical applications of light-measuring devices are examined, and minimum lighting requirements for various activities are discussed. In the laboratory, the student will use a photoelectric light meter to measure the illumination of several rooms.

Prerequisites: 13-0, 13L1, 13L2, 13L3.

13L18, SINGLE LENS REFLEX CAMERA

A single lens reflex camera (SLR) allows the photographer to view a scene, to focus, and to measure light intensity through the same lens used in taking photographs. This module introduces the optics, shutter speed, f-stop (lens opening), metering, film, viewing, and focusing of the SLR camera. In the laboratory, the student will use a convex lens, a Fresnel field lens, a pentaroof prism, and a Polaroid camera to determine image characteristics and depth of focus.

Prerequisites: 13-0, 13L1, 13L9, 13L10.

13N1, GEIGER COUNTERS

This module presents the Geiger counter as an instrument used in the detection and measurement of radiation. The Geiger-Müeller detector is a gas-filled tube that detects radioactive particles, which ionize the atoms of the gas. This ionization produces electrical pulses that register the intensity of radiation. In the laboratory, the student will use an electronic scaler to determine the operating voltage of a Geiger counter, and will measure ionizing radiation produced by a radioactive source.

Prerequisites: 13-0.

13N2, PENETRATING POWER OF ALPHA AND BETA RADIATION

Alpha and beta particles lose energy as they pass through a material because they collide with the electrons in the material and give up energy to them. The distance the particle is able to travel in the material is its "range." This module describes the range of a particle as a function of its energy. In the laboratory, the student will use a Geiger counter to determine the range of alpha and beta particles in metal foils.

Prerequisites: 13-0, 13N4, 13N1.

13N3, RADIOACTIVITY

This module explores radioactivity, the emission of radiation during the decay of the unstable nuclei of atoms. Three different types of radiation, denoted as "alpha," "beta," and "gamma," are produced. Radioactive atoms decay over a period of time and are characterized by a "half-life." For different radioisotopes, half-lives vary from a fraction of a second up to billions of years. In the laboratory, the student will use a Geiger counter to measure the decay rate and source strength of a radioactive source, and will verify the inverse square-law dependence of the counting rate on distance from the source.

Prerequisites: 13-0, 13N4, 13N2, 13N1.

13N4, ABSORPTION OF GAMMA RADIATION

This module discusses the absorption of gamma radiation, which is an electromagnetic radiation that has a wavelength shorter than that of light. The absorption of gamma radiation is described by the same type of exponential equation that characterizes the absorption of light. The absorption coefficient for gamma radiation in a material depends upon the wavelength of the radiation and upon the properties of the absorbing material. In the laboratory, the student will use a Geiger counter to measure the transmission of gamma radiation through lead and aluminum, and will use the results to calculate absorption coefficients for these two materials.

Prerequisites: 13-0, 13N1.

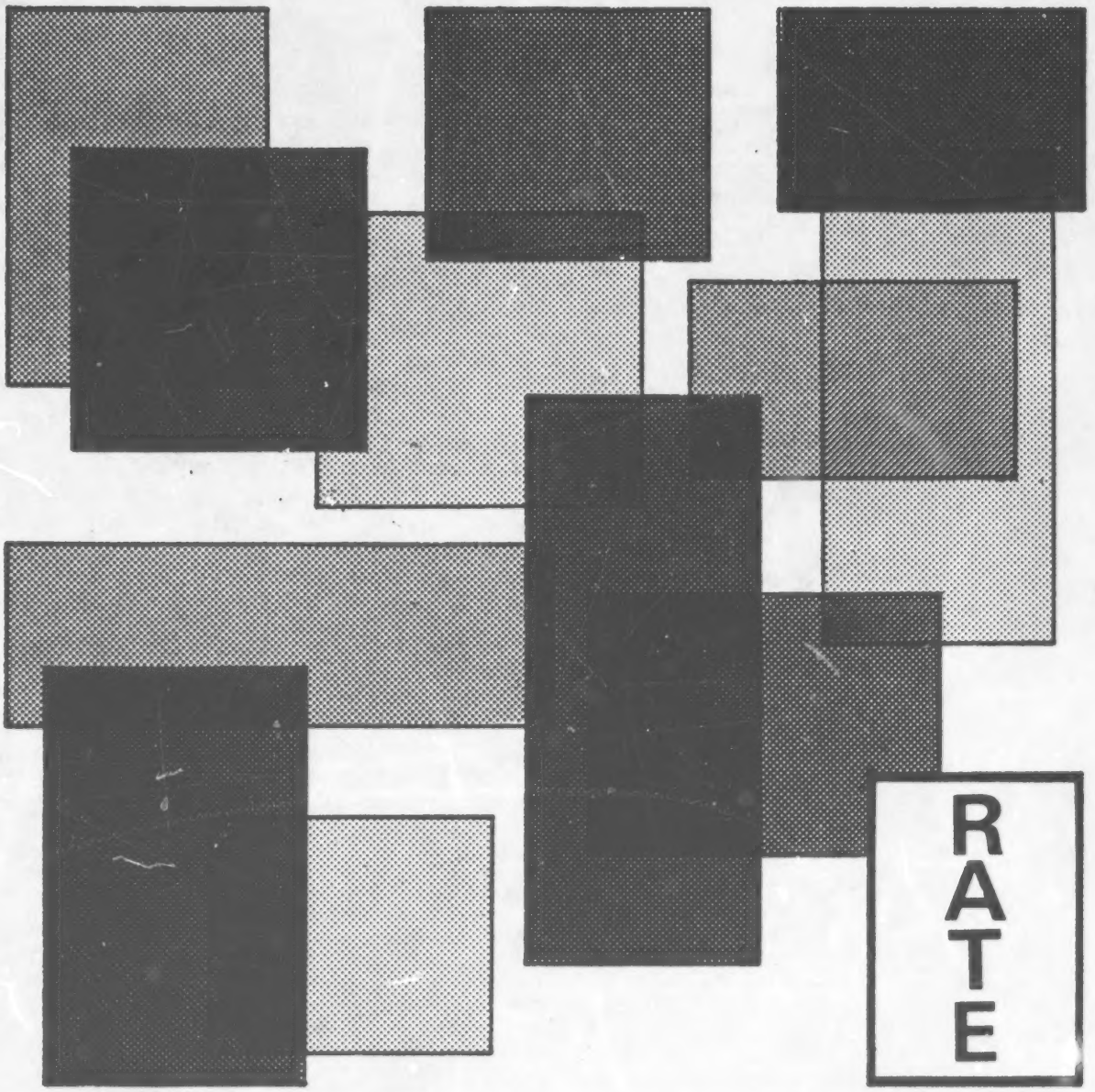
APPENDIX B

EXAMPLE CONCEPT MODULE

UTC

UNIFIED TECHNICAL CONCEPTS

CONCEPT MODULE 3 - 0



TERC-SW

Technical Education Research Center – Southwest

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INTRODUCTION

If a car travels 120 miles in three hours, it travels an average of 40 miles every hour; the car's average speed is 40 miles per hour. Forty miles per hour is referred to as rate of motion or speed of the car. Both distance traveled and time required are used to determine rate of motion. Rate is a quantity that describes how rapidly an occurrance takes place.

This module presents the concept of rate as it applies to mechanical, fluidal, electrical, and thermal systems. In every case, rate expresses the ratio of a displacementlike quantity to an elapsed time:

- In a linear mechanical system, velocity is the ratio of distance traveled to elapsed time.
- In a rotational mechanical system, angular velocity is the ratio of angle of rotation to elapsed time.
- In a fluidal system, volume flow rate is the ratio of volume of fluid moved to elapsed time.
- In an electrical system, current is the ratio of charged transferred to elapsed time.
- In a thermal system, heat flow rate is the ratio of thermal energy transferred to elapsed time.

This module discusses these rates and others and presents the mathematical formulation and units used to express rates in all energy systems.

PREREQUISITES

The student should have completed Concept Module 2-0, "Work."

OBJECTIVES

Upon completion of this module, the student should be able to:

- Define the following rates and, and where applicable, express

their basic units both in SI and English systems of units:

Speed and velocity.
Acceleration.
Angular velocity.
Angular acceleration.
Volume flow rate.
Mass flow rate.
Electric current.
Heat flow rate.

- In a linear mechanical system, given all the quantities except one in each of the following groups, determine the unknown quantity:

  Displacement, elapsed time, velocity.
  Initial velocity, final velocity, elapsed time, acceleration.
  Mass, force, acceleration.

- In a rotational mechanical system, given all the quantities except one in each of the following groups, determine the unknown quantity:

  Angular displacement, elapsed time, angular velocity.
  Initial angular velocity, final angular velocity, elapsed time, angular acceleration.

- In a fluidal system, given all the quantities except one in each of the following groups, determine the unknown quantity:

  Volume of fluid moved, elapsed time, volume flow rate.
  Mass of fluid moved, elapsed time, mass flow rate.

- Given two of the following quantities in an electrical system, determine the third:

  Charge transferred.
  Elapsed time.
  Current.

- Given two of the following quantities in a thermal system, determine the third:

  Heat energy transferred.
  Elapsed time.
  Heat flow rate.

- State the general equation for rate, and explain how it applies to each of the following energy systems:

  Mechanical translational.
  Mechanical rotational.

Fluidal.
Electrical.
Thermal.

Concept Module 1-0, "Force," described forcelike quantities as the physical quantities that cause motion in all energy systems. Concept Module 2-0, "Work," described work done in an energy system in terms of changes that occur in that system as the result of the action of forcelike quantities present. A useful description of the affects of forcelike quantities in a system and work done in that system requires that the time necessary for the changes to occur be considered.

Movement is an occurrence common to every energy system. The rate of movement in each system can be determined by dividing the displacementlike quantity by the time in which the displacement takes place. The unifying formula used for calculation rate is shown in Equation 1.

$$\text{RATE} = \frac{\text{DISPLACEMENTLIKE QUANTITY}}{\text{TIME ELAPSED}} \qquad (1)$$

This module discusses the application of this general rate equation in mechanical, fluidal, electrical, and thermal systems.

MECHANICAL SYSTEMS

MECHANICAL TRANSLATIONAL RATES

The most fundamental rate in a mechanical system is speed. Speed is the rate at which an object moves without regard for the direction of motion of the object. Speed can be calculated by dividing the total length of the path of an object by the time required for the movement along that path. Speed indicates only the rate at which the object moves through some distance; it contains no information concerning the direction of the motion.

Velocity, rather than speed, is used whenever the direction of the moving body is important. Velocity specifies both the speed and direction of the motion. For example, "40 miles per hour" denotes a speed, while "40 miles per hour northeast" denotes a velocity.

When an object moves in a straight line, it is said to be in linear or translational motion. The object may stop or reverse direction, but its motion always lies along the same straight line. This discussion of mechanical translational rates will deal only with cases of straight-line motion. The term "speed" will be used when the direction of motion is not important; velocity will be used when both speed and direction are important. The formula for calculating speed (the magnitude of velocity) in a linear mechanical system is given by Equation 2.

$$v = \frac{d}{t} \qquad (2)$$

where

v = speed (magnitude of velocity).
d = displacement.
t = elapsed time.

The symbol v commonly is used for both speed and velocity. If the quantity identified as v includes a direction, it is the vector quantity velocity. If it does not include a direction, it is the scalar quantity speed.

Example A illustrates how Equation 2 is used to solve a problem.

EXAMPLE A: SPEED AND VELOCITY OF AN AUTOMOBILE

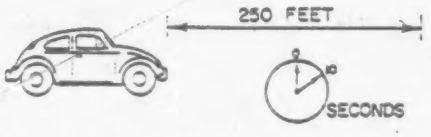
Given: An automobile travels 250 feet east in 10 seconds.

Find: Its speed and velocity.

Solution: Speed: $v = \frac{d}{t}$

$$= \frac{250 \text{ ft}}{10 \text{ s}}$$

$$v = 25 \frac{\text{ft}}{\text{s}}$$



The speed of the automobile is 25 ft/s. If direction is specified, we have a velocity.

Velocity = 25 ft/s, east.

If direction of the moving car in Example A were given as west, the car's velocity would be 25 ft/s, west.

Distance (displacement) often is measured in units such as feet, miles, or meters and time in units such as seconds, minutes, or hours. Common units for speed are summarized in Table 1.

TABLE 1: COMMON UNITS FOR SPEED	
System of Measure	Common Units for Speed
English	ft/s or miles/hour (44 ft/s = 30 mi/h)
SI	m/s or kilometers/hour (0.278 m/s = 1 km/h)

Example B illustrates the use of Equation 2 to determine elapsed time if speed and distance are known.

EXAMPLE B: TIME TO RUN A MILE

Given: A runner can average 13.4 mi/h.

Find: Time required to run one mile.

Solution: Speed $v = 13.34$ mi/h

$$= (13.34 \text{ mi/h})\left(\frac{44 \text{ ft/s}}{30 \text{ mi/h}}\right)$$

$$v = 19.56 \text{ ft/s}$$

From Equation 2: $t = \frac{d}{v}$

$$= \frac{5280 \text{ ft}}{19.56 \text{ ft/s}}$$

$$= 270 \text{ s}$$

$$= (270 \text{ s})\left(\frac{1 \text{ min}}{60 \text{ s}}\right)$$

$$t = 4.5 \text{ min}$$

Both Examples A and B involved average speed of an object. Speed was treated as if it were constant through the entire measured time. However, in many cases the speed of a moving object fluctuates as it moves in a fixed direction. The rate of change of linear speed is called "linear acceleration." A constant linear acceleration is calculated by using the relationship shown in Equation 3.

$$a = \frac{v_2 - v_1}{t} \qquad (3)$$

where

a = linear acceleration.
v_1 = initial speed (speed before change).
v_2 = final speed (speed after change).
t = time in which change takes place.

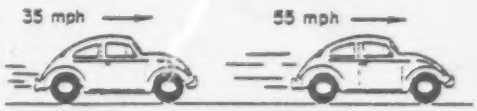
The units of acceleration are velocity units (m/s, ft/s, mi/h) divided by time units. The most commonly-used acceleration units are ft/s^2 and m/s^2. An acceleration of 1 m/s^2 means that the velocity increases by 1 m/s in 1 s.

Example C shows the use of Equation 3 in determining acceleration.

EXAMPLE C: ACCELERATION OF A CAR

Given: A driver increases the speed of a car uniformly from 35 miles per hour to 55 miles per hour in 15 seconds.

Find: Acceleration of the car.



Solution:

$$a = \frac{v_2 - v_1}{t}$$

$$= \frac{55 \text{ mi/h} - 35 \text{ mi/h}}{15 \text{ s}}$$

$$= \frac{20 \text{ mi/h}}{15 \text{ s}}$$

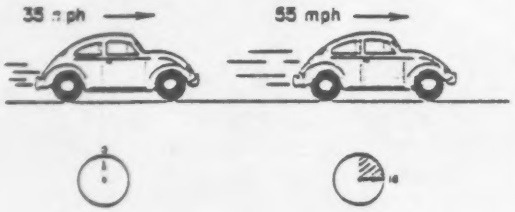
$$a = 1.34 \frac{\text{mi/h}}{\text{s}}$$

The car was accelerated 1.34 mi/h every second.

Units shown in Example C may look strange because two different time units appear. The units often are reduced in order that only one time unit is used. To reduce units in Example C in order that only one time unit is used, the unit for speed is converted from miles per hour to feet per second. Example D shows this alternate solution to Example C.

EXAMPLE D: ALTERNATE SOLUTION FOR EXAMPLE C

Given: A driver increases the speed of a car uniformly from 35 miles per hour to 55 miles per hour in 15 seconds.



Find: Acceleration of the car.

Solution:

$$a = \frac{v_2 - v_1}{t}$$

$$= \frac{(55 - 35)\ \cancel{mi/h}\ (\frac{44\ ft/s}{30\ mi/h}}{15\ s}$$

$$= \frac{29.3\ ft/s}{15\ s}$$

$$a = 1.96\ \frac{ft/s}{s}$$

The units $\frac{ft}{s}$ $\quad s = \frac{ft}{s} = \frac{ft}{s^2}$

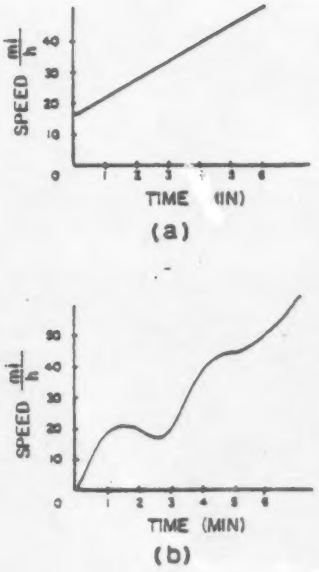


FIG. 1

Acceleration is illustrated better by the graphs in Figure 1, where speed is recorded on the vertical axis, and where time is recorded on the horizontal axis.

A uniform change in speed, indicated on the graph by a straight line, means that linear acceleration is constant. A nonuniform change in speed, indicated on the graph by a curving line, means that linear acceleration is varying. The concepts of speed and acceleration are illustrated further in Figure 2, which represents the changing speed of a car during a short trip.

Section A of the graph shows acceleration of the car as it starts from rest and increases its speed to approximately 10 mi/h. Since the graph rises very rapidly, rate of

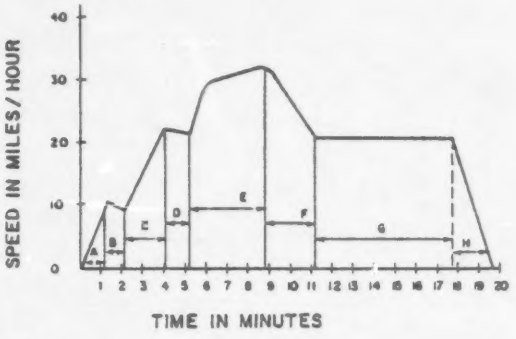


FIG. 2

increase in speed (acceleration) is large. The car in in low gear. Section B represents a slowing down (deceleration) of the car as its gears are shifted from low to second. Section C represents acceleration as the car increases its speed while in second gear. Section D again represents deceleration as gears are shifted from second to third. Section E at first represents an increasing speed and thus an acceleration. But notice that acceleration during Section E does not remain constant. The graph shows clearly that, after the initial high acceleration, the car accelerates less rapidly. Section F shows a rapid deceleration, which must result from a braking action on the part of the driver. Section G shows no acceleration, because the speed does not change during this time. Section H represents a final deceleration, which brings the car to a stop.

Figure 2 indicates clearly both accelerations and decelerations. "Acceleration" is the term generally applied to a rate of increase of speed, and "deceleration" is the term applied to a rate of decrease of speed. If a moving object is decelerating, the value for change of speed in Equation 3 will be negative, giving an overall negative value for acceleration. Thus, deceleration also is called "negative acceleration."

Acceleration is produced only when an unbalanced force sufficient to cause a change in rate of motion is applied to an object. Amount of acceleration produced depends upon both magnitude of the unbalanced force and mass of the object. The greater the unbalanced force on a given object, the greater the acceleration will be. Also, the more massive an object, the harder it is to accelerate. Furthermore, the object always will accelerate in the direction of the unbalanced force. These physical relationships (referred to as Newton's second law of motion) are stated in Equation 4.

$$a = \frac{F}{m} \qquad (4)$$

where

a = acceleration.
F = unbalanced force.
m = mass of object.

This equation often is stated in the form —

$$F = ma$$

To apply this equation, force and mass must be used in correct units. For example, when mass is measured in kilograms and force is measured in newtons $(\frac{kg \cdot m}{s^2})$, acceleration will be in m/s^2. Use of the acceleration formula is illustrated in Examples E and F.

EXAMPLE E: ACCELERATION OF A MASS

Given: An unbalanced force of 35 N is applied to a 7-kg object.

Find: Acceleration produced (neglect friction).

Solution:

$$a = \frac{F}{m}$$

$$= \frac{35\ \text{M}}{7\ \text{kg}} = \frac{35\ \frac{\text{kg}\cdot\text{m}}{\text{s}^2}}{7\ \text{kg}}$$

$$a = 5\ \text{m/s}^2$$

EXAMPLE F: TRUCK DECELERATION

Given: A 5000-kg truck has a speed of 20 m/s.

Find: Braking force required to stop in 60 seconds.

Solution: First, find rate of deceleration:

$$a = \frac{v_2 - v_1}{t}$$

$$= \frac{0 - 20\ \text{m/s}}{60\ \text{s}}$$

$$= \frac{-20\ \text{m/s}\ (1/\text{s})}{60\ \text{s}/1\ (1/\text{s})}$$

$$a = -0.33\ \text{m/s}^2$$

Now, find force required:

$$F = ma$$

$$= 5000\ \text{kg} \cdot -0.33\ \text{m/s}^2$$

$$F = -1650\ \frac{\text{kg}\cdot\text{m}}{\text{s}^2} = -1650\ \text{N}$$

A force of 1650 N is required to stop the truck in the time indicated. The negative sign tells that braking force was applied in a direction opposite to motion of the truck.

Acceleration of a body due to earth's gravity is 32 ft/s^2 or 9.8 m/s^2. This means that a freely-falling body is increasing its velocity an additional 32 ft/s for every second that it falls (assuming that there is no wind resistance). After two seconds, a falling body that started from rest will be falling with a velocity of 64 ft/s, and after five seconds, with a velocity of 160 ft/s. Weight of a body is a measure of the pull of gravity of the mass of that body. This relationship is shown in Equation 5.

$$W = mg \tag{5}$$

where

W = weight (N or lb).
m = mass (kg or slugs).
g = acceleration of gravity.

The importance of using weight and mass correctly is shown by Example G.

EXAMPLE G: TOWING AN AUTOMOBILE

Given: A 3700-lb automobile is being towed on a level road by a towtruck accelerating at 3.8 ft/s^2.

Find: Tension in the towline (force required).

Solution: $F = ma$

Wrong Solution:

F (tension) = (3700 lb)(3.8 ft/s^2)

$$F = 14{,}060 \frac{lb \cdot ft}{s^2}$$

A tention of $\frac{lb \cdot ft}{s^2}$ does not make sense. Tension should be in pounds! What went wrong?

The mistake is that 3700 lb is not the mass but the weight of the car. Therefore, this solution is incorrect.

Correction Solution:

First, find mass of the car being accelerated:

$W = mg$

$m = \frac{W}{g}$

$$m = \frac{3700 \text{ lb}}{32 \text{ ft/s}^2}$$

$$m = 115.6 \frac{\text{lb}\cdot\text{s}^2}{\text{ft}} = 115.6 \text{ slugs}$$

Recall that $\frac{\text{lb}\cdot\text{s}^2}{\text{ft}} = \text{slugs}$

Now, find tension on the rope:

$$F = ma$$
$$= (115.6 \text{ slugs})(3.8 \text{ ft/s}^2)$$
$$= \left(115.6 \frac{\text{lb}\cdot\text{s}^2}{\text{ft}}\right)\left(3.8 \frac{\text{ft}}{\text{s}^2}\right)$$
$$F = 439 \text{ lb}$$

Tension in the towline is 439 lb.

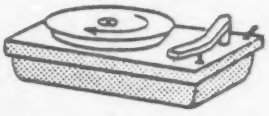
MECHANICAL ROTATIONAL RATES

Rate of rotational motion is called angular velocity. Angular velocity is defined as the rate of change of an angle with time. Common units for measuring angular velocity are revolutions per minute (rpm or r/min) and radians per second (rad/s).

Recall from Module 2-0, "Work," that 1 revolution equals 2π radians. The relationship between rpm and rad/s is illustrated in Example H.

EXAMPLE H: UNITS FOR ANGULAR VELOCITY

Given: A phonograph turntable has an angular velocity of 45 rpm.



Find: The angular velocity in rad/s.

Solution: Angular velocity = $(45 \frac{\text{r}}{\text{min}})(\frac{2\pi \text{ rad}}{1 \text{ r}})(\frac{1 \text{ min}}{60 \text{ s}})$

Angular velocity = 4.7 rad/s.

The angular velocity is 4.7 rad/s.

In the rotational mechanical system, the basic rate equation is Equation 6.

$$\omega = \frac{\theta}{t} \qquad (6)$$

where

ω = angular velocity.
θ = angular displacement.
t = elapsed time.

The use of this equation in determining angular velocity is illustrated in Example I.

EXAMPLE I: ANGULAR VELOCITY

Given: A grindstone rotates 600 revolutions in 5 minutes.

Find: Angular velocity.

Solution:

$$\omega = \frac{\theta}{t}$$

$$= \frac{6000 \text{ revolutions}}{5 \text{ minutes}}$$

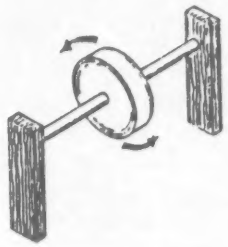
$$= 120 \text{ rpm}$$

$$= 120 \left(\frac{\cancel{\text{rev}}}{\cancel{\text{min}}}\right)\left(\frac{2\pi \text{ rad}}{\cancel{\text{rev}}}\right)\left(\frac{1 \cancel{\text{min}}}{60 \text{ s}}\right)$$

$$= 120 \frac{2\pi \text{ rad}}{60 \text{ s}}$$

$$= 4\pi \text{ rad/s}$$

$$\omega = 12.56 \text{ rad/s}$$



When an unbalanced torque is applied to a rotary system, the angular velocity of that system is changed. The rate at which this change takes place is called "angular acceleration." Angular acceleration can be determined by dividing change in angular velocity by time required for this change. The formula for calculating angular acceleration is given in Equation 7.

$$\alpha = \frac{\omega_2 - \omega_1}{t} \tag{7}$$

where

α = angular acceleration.
ω_1 = initial angular velocity (before change).
ω_2 = final angular velocity (after change).
t = time in which the change takes place.

Example J shows how the formula can be used to solve a problem.

EXAMPLE J: ANGULAR ACCELERATION

Given: A brake is applied to a flywheel for 5 seconds, reducing angular velocity of the flywheel from 2.2 rad/s to 1.8 rad/s.

Find: Angular acceleration produced.

Solution:

$$\alpha = \frac{\omega_2 - \omega_1}{t}$$

$$= \frac{1.8 \text{ rad/s} - 2.2 \text{ rad/s}}{5 \text{ s}}$$

$$= \frac{-0.4 \text{ rad/s}}{5 \text{ s}}$$

$$\alpha = 0.08 \text{ rad/s}^2$$

Angular acceleration produced is -0.8 rad/s^2. The negative sign indicates this is a deceleration of 0.08 rad/s^2.

FLUIDAL SYSTEMS

The rate of flow of fluids is often an important consideration in hydraulic and pneumatic systems. However, a measure of fluid velocity is not in itself adequate to describe flow rate, since the volume or capacity of fluid moving through a duct or pipe must be considered. Thus, one measures volume per second, rather than simply distance per second. For example, if the velocity of fluid in two pipes is the same, less fluid will flow through a small pipe in the same time, as illustrated in Figure 3. The volume of fluid that flows in a given time is much more important. This quantity is called the "volume flow rate." It is found by dividing a measured volume by the time required for this volume to flow from a pipe. Equation 8 shows the formula for calculating volume flow rate. Note that the displacementlike quantity in this instance becomes the volume of fluid moving past a certain position in the elapsed time.

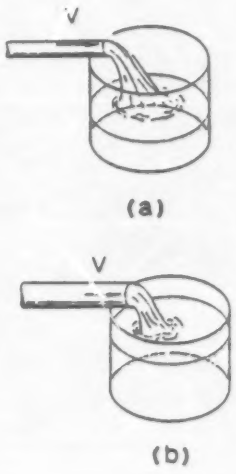


FIG. 3

$$Q_V = \frac{V}{t} \qquad (8)$$

where

Q_V = volume flow rate.
V = volume of fluid displaced.
t = elapsed time.

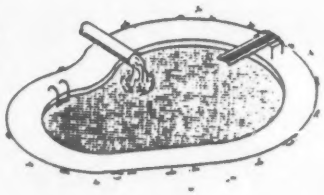
Units of volume flow rate could be any volume unit divided by any time unit. Examples include the following: m^3/s, ft^3/s, gal/min, liters/s, cm^3/s. Example K illustrates how volume flow

rate is calculated.

EXAMPLE K: VOLUME FLOW RATE

Given: A swimming pool holds 10,000 gallons; 2 hours are needed to fill pool.

Find: Volume flow rate of water through the hose.



Solution:

$$Q_V = \frac{V}{t}$$

$$= \frac{10{,}000 \text{ gal}}{(2\text{h})\left(\frac{60 \text{ min}}{1 \text{ h}}\right)}$$

$$Q_V = 83 \text{ gal/min}$$

For some purposes (especially for gases), the desirability arises to consider mass flow rate rather than volume flow rate. Mass flow rate is defined as "the fluid mass moving past a given position in a given amount of time." Equation 9 defines mass flow rate. Note that here the displacementlike quantity becomes the mass moving past a fixed position in the elapsed time.

$$Q_m = \frac{m}{t} \tag{9}$$

where

Q_m = mass flow rate.
m = mass of fluid displaced.
t = elapsed time.

Example L shows how flow rate can be calculated.

EXAMPLE L: MASS FLOW RATE

Given: 180 kg of ammonia gas flowing through the cooling coils of a refrigerated truck in 6 minutes.

Find: Mass flow rate of the gas.

Solution:

$$Q_m = \frac{m}{t}$$

$$= \frac{180{,}000 \text{ g}}{6 \text{ min}}$$

Q_m = 30,000 g/min = 30 kg/min

The ammonia gas is flowing at a rate or 30,000 grams/minute of 3 kg/min.

ELECTRICAL SYSTEMS

In electrical systems the displacementlike quantity is charge. Recall from Module 1-0, "Force," that like charges attract and unlike charges repel. This characteristic of electrical charge results in a tendency for positive and negative charges to be distributed as evenly as possible in an electrical system. If the system contains a concentration of positive charge in one volume and a concentration of negative charge in another, a potential difference (forcelike quantity) is present. If charges are free to move, the potential difference will cause charge to flow until the system is in electrical equilibrium. Electric current is the rate of charge flow and is defined by Equation 10.

$$I = \frac{Q}{t} \qquad (10)$$

where

I = electric current.
Q = charge transferred.
t = elapsed time.

Current is measured in amperes (amp or A). One ampere is equal to one coulomb of charge flowing each second. In metallic electrical conductors the moving charge is composed of electrons that flow through the metal. There are 6.25×10^{18} electrons in one coulomb. Thus, a current of one amp represents a transfer of 6.25×10^{0} electrons from the point of negative potential to the point of positive potential every second. Example M illustrates the use of Equation 10 in determining the charge transferred in a household circuit.

EXAMPLE M: ELECTRICAL CURRENT

Given: A home electrical circuit is limited to 15 amps by a fuse or circuit breaker.

Find: How many electrons have flowed through the circuit in 10 seconds when it has a maximum load.

Solution: A current of 15 amps is equivalent to a flow rate of

15 coulombs/seconds.

$$I = \frac{Q}{t}$$

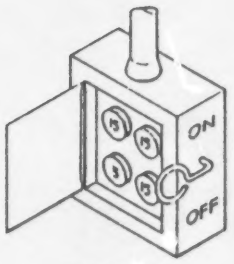
$$Q = It$$

$$= (15\ C/s)(10\ s)$$

$$= 150\ C$$

$$= (150\ C)\left(\frac{6.25 \times 10^{18}\ \text{electrons}}{1\ C}\right)$$

$$Q = 9.4 \times 10^{20}\ \text{electrons}$$



FUSE BOX

Alternating current (a.c.) and direct current (d.c.) are terms that refer to the direction in which electrical charge moves. Direct current means that electrical charge flows in one direction only, even though the amount of current may vary. In alternating current, the direction of the current changes (alternates) so that the charge flows back and forth. Commercial power companies generate electric current that changes direction at the rate of 120 times each second. (The popularity of a.c. arises from its ability to transmit electrical energy great distances without large heat losses in the wires. One advantage in the use of a.c. electricity in our homes is that a smaller wire will carry more current.)

THERMAL SYSTEMS

In any system where a temperature difference exists, heat moves from the high-temperature region to the low-temperature region. Movement in this system, however, is different from movement in the other energy systems discussed in this module. In other systems, an object of some kind moves from one location to another; in thermal systems, the quantity that moves is heat energy. This energy is contained in a substance in the form of vibrational energy of the molecules. A higher temperature indicates a higher vibrational rate of the molecules and thus a greater quantity of heat energy contained in the substance.

In any substance, heat energy is transferred when an energetic vibrating molecule bumps a neighboring molecule with a lower vibrational rate. The more-energetic molecules loses some of its thermal energy and its vibrational rate decreases; the less-energetic molecule gains this energy and its vibrational rate increases. This process continues in a closed system until the thermal energy is evenly distributed and there is no longer a temperature difference.

Heat flow rate is the amount of heat energy flowing through a surface in a given amount of time. The formula used to calculate heat flow rate is given in Equation 11. Here the displacementlike

quantity is less clear than distance, volume or mass. In thermal systems, it becomes a measure of the heat energy flow past a fixed position in the time elapsed.

$$Q_H = \frac{H}{t} \qquad (11)$$

where

Q_H = heat flow rate.
H = heat energy transferred.
t = elapsed time.

Designers of heating and cooling systems are vitally concerned with rate of heat flow. Manufacturers' specifications for heating and cooling systems, however, sometimes are misleading, because they are given in units of Btu's. This terminology is misleading, because what the manufacturer means by "Btu's" is actually "Btu's per hour," which is a heat flow rate. For instance, a 10,000-Btu air conditioner is capable of removing room heat at a rate of 10,000 Btu's every hour. Example N shows how Equation 11 is used to solve problems involving heat flow rate.

EXAMPLE N: HEAT FLOW RATE

Given: A 5000-Btu tent heater runs continuously for 5 hours and 30 minutes.

Find: Amount of energy produced.

Solution: The 5000-Btu specification means a heat flow rate of 5000 Btu/hour.

$$Q_H = \frac{H}{t}$$

$$H = Q_H t$$

$$= (5000 \text{ Btu/h})(5\ 1/2 \text{ h})$$

$$H = 27{,}500 \text{ Btu}$$

SUMMARY

The concept of rate is important in all energy systems. Any change in a system takes place in a certain elapsed time. Rate is the ratio of change in a physical quantity to the time required for that change. This module has dealt with the basic rates in four energy systems — mechanical, fluidal, electrical, and thermal. Many other rates commonly are used in science and technology. Some of these are discussed in application modules. One rate is so important that it is considered to be a separate unifying concept. Power is the rate of energy transfer and will be discussed in detail in Module 6-0, "Power."

Table 2 summarizes the basic rates presented in this module.

TABLE 2: RATE AS A UNIFYING CONCEPT

ENERGY SYSTEM	$\text{RATE} = \frac{\text{DISPLACEMENTLIKE QUANTITY}}{\text{ELAPSED TIME}}$
MECHANICAL	
Translational	$\text{Velocity} = \frac{\text{Displacement}}{\text{Elapsed Time}}$
Rotational	$\text{Angular Velocity} = \frac{\text{Angular Displacement}}{\text{Elapsed Time}}$
FLUIDAL	$\text{Volume Flow Rate} = \frac{\text{Volume Displaced}}{\text{Elapsed Time}}$
	$\text{Mass Flow Rate} = \frac{\text{Mass Displaced}}{\text{Elapsed Time}}$
ELECTRICAL	$\text{Current} = \frac{\text{Charge Transferred}}{\text{Elapsed Time}}$
THERMAL	$\text{Heat Flow Rate} = \frac{\text{Heat Energy Transferred}}{\text{Elapsed Time}}$

MECHANICAL SYSTEMS

MATERIALS

Toy car, either wind-up or battery powered.
2-meter track for car.

PROCEDURE

The student is to use a wind-up or a battery powered toy car to calculate velocity of the car and speed with which the wheels turn.

1. Mark "start" and "finish" lines on a straight course at least two meters long.
2. Start car a reasonable distance in front of "start" line (to allow speed to become steady); time car carefully as it travels from "start" to "finish" line. Record this time in Data Table 1.
3. Calculate average speed of car in m/s, ft/s and mi/h.
4. Measure wheel diameter on car and list in Data Table 1.
5. Calculate wheel circumference, $c = \pi d$.
6. Divide raceway length by wheel circumference to determine how many times wheel rotated while it traveled across raceway.
7. Calculate angular velocity of wheel in rpm and in rad/s.

DATA TABLE 1	
Raceway length _____	
Time from start to finish _____	
Average speed (calculated) _____	m/s
_____	ft/s
_____	mi/h

Wheel diameter _____ mm

Wheel circumference ($c = \pi d$) _____ mm

Number of rotations to cover raceway _____ revolutions

Angular velocity of wheel (calculated) _____ rpm

_____ rad/s

FLUID SYSTEMS

MATERIALS

Gallon or liter container.
Meter stick.
Stopwatch or timer.
Balance.

PROCEDURE

Several cooling systems require a specified volume flow rate for adequate operation. Specified values may be given in units of gallons per minute or liters per minute. In this experiment, a water faucet is used to simulate a discharge pipe from a cooling system and to calculate volume flow rate coming from the faucet (Figure 4).

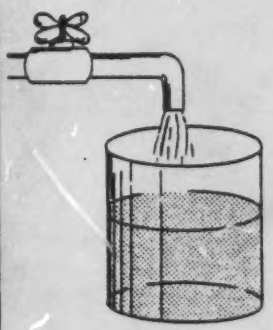


FIG. 4

1. Collect flowing water in a container such as a gallon or liter container; accurately measure time required to fill container.

2. Record values in Data Table 2. From these measurements, calculate volume flow rate in both gallons per minute and in liters per minute. Enter values in Data Table 2.

3. Using a balance scale, determine mass of water in container.

4. Calculate mass flow rate in kilograms per minute and in slugs per minute. Enter values in Data Table 2.

DATA TABLE 2	
Container volume	_____
Time to fill container	_____
Mass of water in container	_____
Volume flow rate	_____ gal/min
	_____ l/min
Mass flow rate	_____ kg/min
	_____ slugs/min

THERMAL SYSTEMS

MATERIALS

Conductometer (Sargent Welch #1653 or equivalent).
Bunsen burner or candle.
Paraffin.

PROCEDURE

Heat flows more rapidly through some materials than through others. This experiment determines which of the materials tested allows the greatest heat flow rate. The instrument used to make these determinations is the "Conductometer," a device having several spokes radiating outward from the central hub, as illustrated in Figure 5.

FIG. 5

1. Place a piece of melted paraffin on end of each spoke; allow it to cool.

2. Place a lighted bunsen burner (or candle) under central hub. Observe which spokes have most rapid head flow by noting the order in which paraffin pieces melt. List the metals in order, from most rapid head flow rate to slowest heat flow rate. (1) _____ (2) _____ (3) _____ (4) _____ (5) _____ (6) _____.

ELECTRICAL SYSTEMS

MATERIALS

6- or 12-volt battery or d.c. power supply.
6- or 12-volt d.c. bulb with mounting base and connecting wires.
d.c. ammeter 0- to 2-amp.

PROCEDURE

Rate of flow of electric charge (electric current) is measured with an ammeter. Place ammeter in an electric circuit along with a battery and a small d.c. light bulb, according to Figure 6. How much electric current is recorded by milliammeter when the bulb is lit?

Current = _____.

How many coulombs/s is this? _____.

If the light bulb burns for one hour, how many electrons have moved through bulb filament?

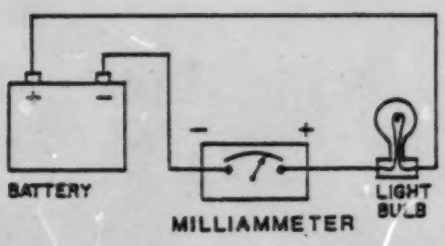


FIG. 6

SELF CHECK

1. Define the following rates, and express their basic units both in the SI and the English system of units:

   Linear speed.
   Linear acceleration.
   Angular velocity.
   Angular acceleration.
   Volume flow rate.
   Mass flow rate.
   Electrical current.
   Heat flow rate.

2. Calculate an airplane's average speed if it travels 3200

kilometers in 3.5 hours.

3. If a car traveling at 55 miles per hour stops in 16.3 seconds, calculate the car's deceleration in ft/s^2.

4. If a driver averages 55 mi/h, how much time will be required to make a 250-mile trip?

5. A force of 200 N accelerates an object with a mass of 100 kg. If the object was initially at rest, determine its speed after 3 seconds.

6. A flywheel of radius 60 cm initially at rest requires 25 seconds to reach an angular velocity of 1750 r/min. Calculate angular acceleration of the flywheel.

7. A motor rotates at a rate of 5000 rpm. How much time is required for one complete revolution?

8. A gas pump moves gasoline from an underground storage tank to the tank in a car at the rate of 15 liters per minute. Calculate time required to fill a 20-gallon gas tank with this pump.

9. If an air conditioner is rated at 10,000 Btu's, calculate how much heat energy it will remove from a room in one day if it operates 20% of the time.

10. Electric current flows at the rate of 0.5 amps through a normal 60-watt light bulb. Calculate how many coulombs of electric charge this represents in 12 hours of continuous operation.

11. State the general equation for rate; and explain how it applies to mechanical, fluidal, electrical, and thermal energy systems.

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See especially Chapters 15, 17, 21, 25.

APPENDIX C

EXAMPLE APPLICATION MODULE

UTC

UNIFIED TECHNICAL CONCEPTS

MODULE 2 T 4

FUNDAMENTALS OF AIR CONDITIONING

THERMAL APPLICATION OF WORK

Technical Education Research Center - Southwest

TERC - SW

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INTRODUCTION

The process of cooling an object or an area is accomplished by work, which removes heat from either. Heat is energy; therefore, heating and cooling basically are processes of moving energy from one place to another. Fans, pumps and motors are used to move energy through a system. If a fan is placed in a window and used to pull warm air from the house, while another window fan pulls in cooler evening air to replace it, the fans are moving heat energy. When a fan is directed at somebody, that person experiences a cooling effect, since evaporation of body moisture carries away excess body heat. More complex systems that are capable of moving larger quantities of heat energy have been constructed, creating the air-conditioning or refrigeration effects. This module introduces the basic principles of air conditioning, including energy and cost efficiency. In the laboratory, the student will determine energy and cost efficiency, and will measure temperature of an air-conditioning system.

PREREQUISITES

Student should have completed Concept Module 2-0, "Work."

OBJECTIVES

Upon completion of this module, the student should be able to:

- Define the following terms:

  Calorie.
  Kilocalorie.
  Btu.
  Mechanical equivalent of heat.
  EER (energy efficiency ratio).
  Btu/h.

- Determine the EER (energy efficiency ratio) of an air conditioning unit, given the Btu/h and watts input.

- Given the necessary data, calculate the cost difference per day of air conditioners with different EERs.
- Draw a schematic diagram, illustrating the parts of an air conditioning unit; and describe the temperature and pressure changes that take place within the system.
- Given the appropriate equipment, determine cost and energy efficiency of an air-conditioning unit, and measure temperatures of an air-conditioning system.

DISCUSSION

Heat (energy) applied to a body causes the temperature of the body to rise. In fact, this relationship is how the basic unit of heat is defined. There are three common units in use today for measuring heat energy:

The Calorie.
The Kilocalorie.
The British thermal unit (Btu).

The heat unit most commonly used in refrigeration and air conditioning theory is the Btu, which is the quantity of heat that must be supplied to one pound of water to raise its temperature one degree Fahrenheit (Figure 1).

A calorie is the quantity of heat required to raise 1 gram of water through one Celsius degree; therefore, a kilocalorie is the quantity of heat required to raise 1 kilogram of water through one Celsius degree.

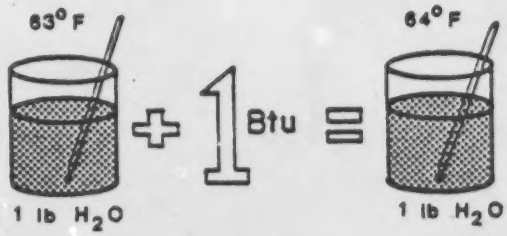


FIG. 1

In all three of these definitions, heat itself is not directly observed; rather, the change (temperature) that it produces. The conversion between units is given by the following relations:

1 kilocalorie = 1000 calories.
1 Btu = 252 cal = 0.252 kilocalorie.

Before mechanical refrigeration was invented, ice was used to refrigerate. A ton of ice melting in 24 hours absorbs heat at the rate of 12,000 Btu per hour. This figure has carried over into the field of mechanical refrigeration in such a manner that a refrigeration system which removes heat at the rate of 12,000 Btu per hour is said to have a capacity of "one ton." The Btu rating of an air conditioner needed to cool a house of a given size can be calculated as shown in Example A.

Energy in mechanical systems usually is expressed in ft·lbs, ergs or joules. Energy in the form of heat is expressed in calories or Btu's. The relative magnitudes of the "mechanical units" and the "heat units" of energy are known quite accurately and are given as follows:

1 Btu = 778 ft·lb.
1 calorie = 4.186 joules.
1 kilocalorie = 4186 joules.

EXAMPLE A: CONVERTING TON CAPACITY TO BTU'S	
Given:	A 2700 ft^2 home, for which there is an estimated requirement for a 5-ton air-conditioning unit.
Find:	The number of Btu per hour (Btu/h) removed from the home by this system.
Solution:	$H\ (Btu/h) = \text{Tonnage} \times \frac{12{,}000\ Btu/h}{1\ ton}$
	$= 5\ ton \times \frac{12{,}000\ Btu/h}{1\ ton}$
	$H\ (Btu/h) = 60{,}000\ Btu/h$

These relations are often expressed in ratio form, and are called "the mechanical equivalent of heat." Thus, 4.186 joules/calorie or 778 ft·lb/Btu are mechanical equivalents of heat.

Mechanical cooling by use of an air conditioner may seem complex; however, the process is merely an application of several principles that already should have been studied. These principles can be summarized in a series of four statements, which should be kept in mind as the functioning of an air conditioner is described. They are as follows:

- As a gas is compressed, its temperature increases.
- Removing sufficient heat energy from a gas causes it to liquefy.
- A liquid under pressure boils at a higher temperature.
- Boiling liquids absorb energy (heat).

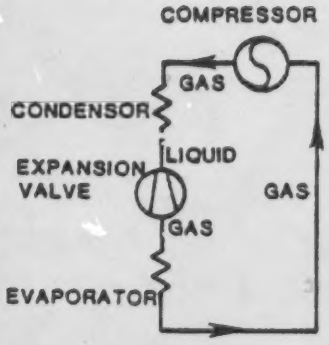


FIG. 2

Freon-12 is a gas vapor at room temperature and pressure. Many air-conditioning systems use this gas or a similar one. Freon is put into an air-conditioning system at a certain pressure. The continual change of the freon back and forth between its gas and liquid phases forms the basis for the air-conditioning system. Figure 2 illustrates the changing state of freon through the air conditioner. A detailed explanation follows.

Freon is introduced into a system and maintained there at a minimum pressure of about 70 psi. The freon starts at the compressor (Figure 2) at about room temperature and at 70 psi. Figure 3 shows that the compressor increases the pressure of the freon in the system. As a result of the increased pressure, there also is an increase in gas temperature. At 200 psi, freon turns to a liquid

at about 110°F. Since the gas is now at about 140°F, it will liquefy if cooled by 30 degrees. Liquefaction will be the next step in the process.

The gas is passed through the condenser coils, which function like an automobile radiator. A fan draws outside air past the coils, removing heat from the hot, circulating gas. The freon thus is cooled sufficiently to liquefy (Figure 4).

When liquid freon reaches the expansion valve, it is allowed to drop in pressure to about 70 psi. The lower pressure allows the liquid freon to boil as it rushes into the evaporator coils. The evaporator, acting as a "reverse radiator," supplies the heat energy needed for the freon to boil or vaporize. Necessary heat is supplied by the warm room air as it passes over the evaporator. The air passing over the evaporator is cooled (Figure 5) and is circulated back into the room to lower the ambient temperature.

The gaseous freon now is returned to the compressor, and the cycle repeats itself. Figure 6 summarizes the entire system.

The efficiency of air conditioners becomes increasingly important because of dwindling energy supplies and increasing costs. The energy efficiency ratio (EER) of a central air-conditioning unit is an important factor that determines cost of operation. The energy efficiency ratio measures the amount of cooling an air-conditioning system accomplishes per watt of electricity used. It is arrived at by dividing the Btu/h capacity by the wattage input. The more efficiently an air conditioner operates, the less electricity it uses, and the more money and energy are saved.

The EER of several air conditioning systems are listed in Figure 7.

FIG. 3

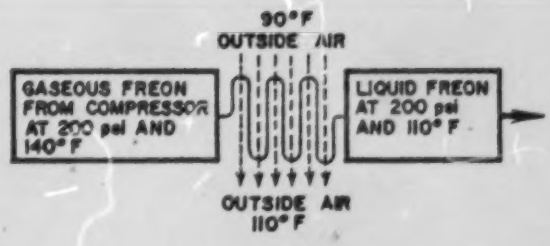


FIG. 4

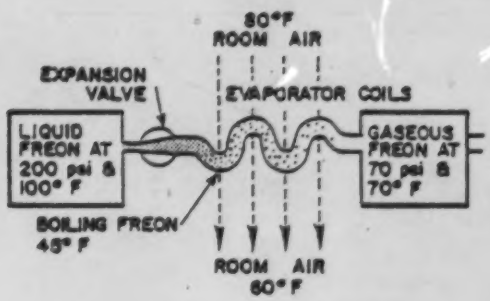


FIG. 5

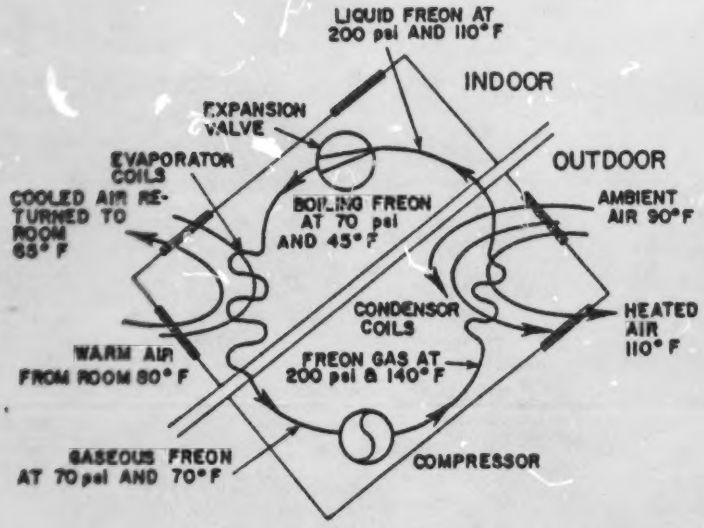
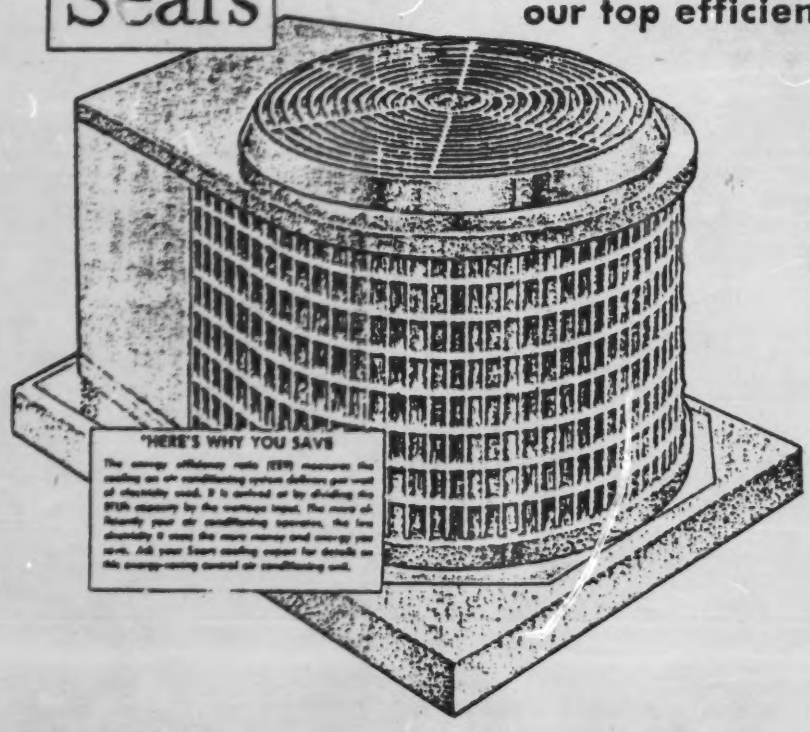


FIG 6

Sears

Our lowest priced central air units with our top efficiency ratings*



Special Purchase
Limited quantities

$529

24,500 BTUh condensing unit, A coil.
Tubing, thermostat, installation, extra

The large condenser and efficient use of air flow give this central air conditioning system the highest Energy Efficiency Rating of any we sell. Condenser unit has up-flow design with single-speed fan motor. Air is drawn in at the sides and exits out the top to prevent damage to shrubbery.

System	E.E.R. (Energy Efficiency Rating)	Sears low price
29,000 BTUh	9.4	$549
33,000 BTUh	9.6	$619
36,500 BTUh	9.0	$689
42,000 BTUh	8.4	$789
47,000 BTUh	8.4	$899
56,000 BTUh	8.1	$989

All systems rated in accordance with Air Conditioning and Refrigeration Institute Standard 210-75.

Ask about Sears Credit Plans

Available at most larger Sears retail stores in area

FIG 7

C10

EER and cost-effectiveness calculations for specific units are shown in Example B.

EXAMPLE B: COMPARING UNITS WITH DIFFERENT EER'S

Given: An air-conditioning system with an EER of 10 as compared to a system with an EER of 5.

Find: The amount of money saved, using this system.

Solution: Assume that 30,000 Btu/h are to be removed from the house by either unit.

$$EER = \frac{Btu/h}{wattage} = 10$$ (Consider the more efficient system first.)

$$Wattage = \frac{Btu/hr}{10} = \frac{30,000}{10} = 3000 \text{ W or } 3.0 \text{ kilowatts}$$

If electricity costs 7¢ per kilowatthour, and if the system is run continuously 24 hours per day, the cost for one day's use of this system would be as follows:

$$Cost = 3.0 \text{ kilowatts} \times 24 \text{ hours} \times \frac{7¢}{\text{kilowatthour}}$$

$$= \$5.04 \text{ per day}$$

$$EER = \frac{Btu/h}{wattage} = 5$$ (Consider the less efficient system next.)

$$Wattage = \frac{30,000}{5} = 6000 \text{ watts} = 6 \text{ kilowatts}$$

$$Cost = 6 \text{ kilowatts} \times 24 \text{ hours} \times \frac{7¢}{\text{kilowatthour}}$$

$$= \$10.08 \text{ day}$$

If the EER is doubled, the efficiency is doubled; and the costs are then cut in half.

SUMMARY

Through mechanical work, the air conditioner produces a temperature difference that results in the cooling of objects or areas. Freon (or similar gas) is compressed by the compressor and is vaporized at the expansion valve, at which point cooling results.

COST AND ENERGY EFFICIENCY OF AN AIR CONDITIONER

MATERIALS

Air conditioning unit or system.
Electrical and thermal specifications for the air conditioning system.

PROCEDURE

1. From an installed air conditioner or a manufacturer's specification sheet, obtain the following published information:

   Power consumption _____ watts.

   Cooling capacity (H) _____ Btu/h.

   Energy efficiency ratio _____ (EER).

   Note: The information on an installed unit is located on a metal plate located on the housing of the outside compressor unit.

2. Calculate the EER of the unit by dividing the cooling capacity in Btu/h by the power consumption:

$$EER = \frac{Btu/h}{wattage}$$

   Compare this value to the published EER rating.

3. From an air conditioning dealer, obtain the following information:

   Installed cost of several air conditioning units with different EERs.
   Average operating cost (utility bills) per year for each unit.

4. Calculate the total cost over 10 years for each unit according to this formula: Total cost = cost of unit + 10 x (annual

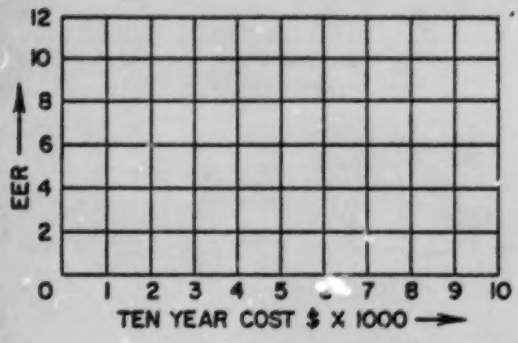


FIG. 8

operating cost). Plot this data as a function of EER (Figure 8).

5. Which air conditioner (EER) is more economical to own?

6. Repeat step 4, assuming that the cost of electrical power has doubled. Plot the data as a function of EER (Figure 9).

7. Under this condition, which air conditioner is more economical to own?

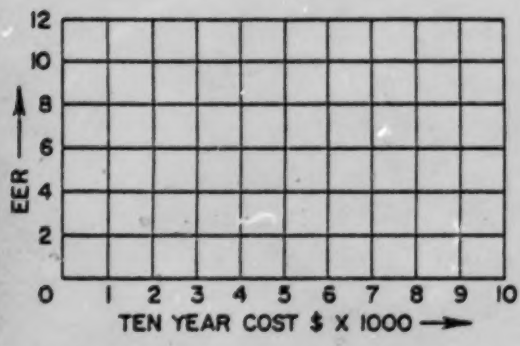


FIG. 9

MEASURING TEMPERATURES OF AN AIR-CONDITIONING SYSTEM

MATERIALS

Contact thermometer (thermocouple).
Air conditioning unit or system.
Electrical and thermal specifications for the air conditioning system.
Graph paper.

PROCEDURE

Note: This procedure should be considered optional (at the discretion of the instructor), since it can only be performed at certain times of the year.

1. Use standard mercury thermometer to measure air temperature at the following locations in or near operating air conditioner:

   Inside a building at return-air register.
   Inside a building at cool-air outlet to a room.
   Ambient temperature of outside air.
   Temperature of outside air as it leaves condenser coils (while fan is blowing).

2. If possible, measure temperature of two copper pipes containing freon at point outside the building where they enter compressor unit. (Use contact thermocouple thermometer.)

   - The cooler pipe is carrying freon entering compressor.
   - The hotter pipe is carrying freon leaving condenser.

3. Record data from steps 1 and 2. Compre these six temperature readings to the typical values shown in Figure 6.

DATA TABLE						
Temperatures °F	Warm Air From Room	Cooled Air Returned To Room	Outside Ambient Air	Outside Hot Air From Condenser	Freon Entering Condenser	Freon Leaving Condenser
From Figure 6						
Measured value						

SELF CHECK

1. Define the terms:

   Calorie.
   Kilocalorie.
   Btu.
   Mechanical equivalent of heat.
   EER.
   Btu/h.

2. Determine the EER from a specification plate on a window air conditioner listing the following information:

   18,000 Btu/h.
   220 V.
   2250 watts.

3. Calculate the 24-hour cost of each of these air conditioners with the following specifications: (electricity cost 6¢/kilowatthour)

   12,500 Btu/h, 1559 watts.
   18,000 Btu/h, 2250 watts.
   24,000 Btu/h, 2665 watts.

4. Draw a schematic diagram illustrating the parts of an air-conditioning unit, and describe the temperature and pressure changes that take place within the system.

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APPENDIX D

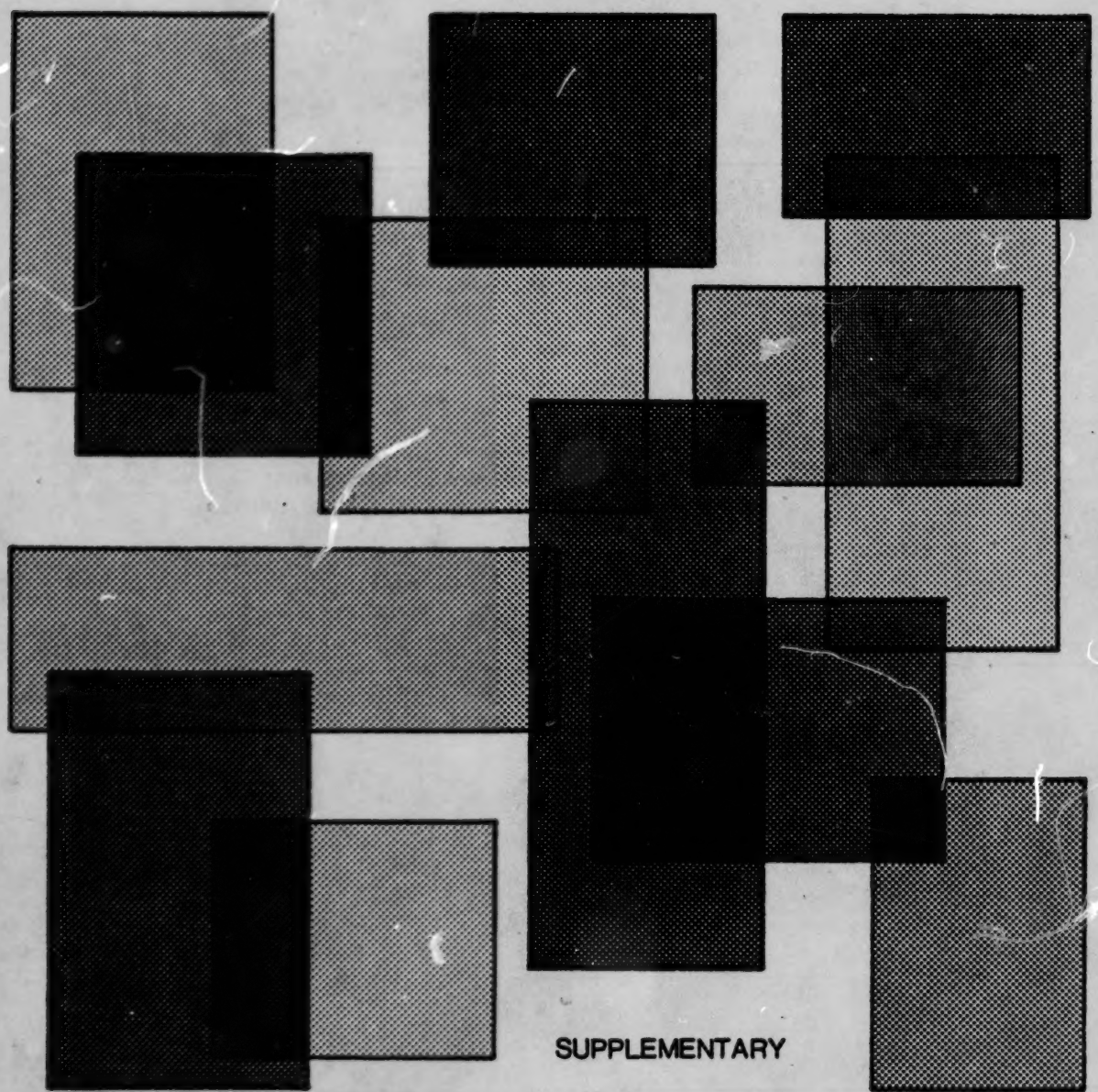
EXAMPLE SUPPORT MODULE

UTC

UNIFIED TECHNICAL CONCEPTS

MODULE S 2

INTERNATIONAL SYSTEM OF UNITS



SUPPLEMENTARY

TERC-SW

Technical Education Research Center – Southwest

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INTRODUCTION

Physics is an attempt to explain, in precise terms, the interactions of matter and energy. This attempt requires a consistent system of units for measuring and describing all the properties of matter and energy. The International System of Units (abbreviated SI for the French name Le Systéme International d'Unités) is the accepted system of units for science and technology throughout the world. This module discusses the units within the SI system, prefixes used with these units, proper procedure for writing SI units, and conversions from SI units to English units.

PREREQUISITES

Student should have completed Support Module S1, "Formula Interpretation." One year of high school algebra is recommended.

OBJECTIVES

Upon completion of this module, the student should be able to:

- Name the seven base SI units, and give the symbol and quantity measured for each.
- Name the two supplementary SI units, and give the symbol and quantity measured for each.
- List the derived SI unit and its symbol for each of the following quantities:

  Frequency.
  Force.
  Energy.
  Power.
  Electrical charge.
  Electrical potential.
  Electrical resistance.

- State the name and symbol of the prefix for each of the following multiples: 10^{12}, 10^{9}, 10^{6}, 10^{3}, 10^{-2}, 10^{-3}, 10^{-6}, 10^{-9}, 10^{-12}, 10^{-15}, 10^{-18}.

- Given quantities expressed in SI units, use prefixes to write an expression for the same quantity with the numerical values between 0.1 and 1000.

- Write, in the accepted notation, expressions indicating the products, quotients, and reciprocals of given SI units.

- Name one non-SI unit that may be used with SI units for measuring the following quantities:

  Time.
  Plane angle.
  Volume.
  Mass.

- Convert lengths in feet and inches to the equivalent length in SI units.

- Given a mass in kilograms, calculate the weight in pounds.

ORIGIN OF THE INTERNATIONAL SYSTEM OF UNITS

The International System of Units, a concise set of units allowing measurement of all physical quantities, was adopted by the International Organization of Standardization in 1972. The basis of the SI system is the older metric system. This system was chosen because it is a decimal system; that is, each unit for a particular quantity is related to all other units for that quantity by a multiple of ten.

All standards of measurement are arbitrary. Their virtue lies in the fact that they are useful, reproducible, and accepted by those who use them. The original meter was intended to be one ten-millionth the distance from the north pole to the equator, along a line passing through Paris. This distance was indicated by two fine lines scribed on gold plugs in an X-shaped platinum-iridium bar. When this bar is at 0°C (the temperature of melting ice), the distance between the marks is defined as one meter. This distance actually is different from the original intended distance by 0.023%; but this is unimportant, because the standard is arbitrary.

The standard kilogram originally was intended to be the mass of 1000 cm^3 of pure water at 4°C. Once again, this measurement is not exactly accurate. One kilogram is defined to be equal to the mass of a platinum-iridium cylinder called the "standard kilogram," and carefully preserved. The second was chosen arbitrarily as 1/86,400th the duration of the average solar day. Modern definitions of the meter and of the second are more precise; they are given later in this module.

Several other quantities besides length, mass, and time must be measured for a complete description of the physical world. There are many ways of defining basic units. All electrical units, for example, could be defined in terms of voltage, current, or charge. In the SI system, current has been chosen arbitrarily as the fundamental quantity. Once a system of base units has been established, all other necessary units can be derived from them. In any measurement system, the base units are arbitrary.

UNITS IN THE SI SYSTEM

There are three classifications of units in the SI system. The base units are given in Table 1, along with their symbols and the fundamental quantities they are used to measure. The definition of each base unit is completely arbitrary and is independent of all other base units. Their exact definitions appear later in this module.

TABLE 1. SI BASE UNITS		
Quantity	Name of base SI unit	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

Table 2 lists the two supplementary units of the SI system. These units are used to measure plane and solid angles and do not meet the exact criteria for either base or derived units.

TABLE 2. SI SUPPLEMENTARY UNITS		
Quantity	Name of Supplementary SI Unit	Symbol
plane angle	radian	rad
solid angle	steradian	sr

A large number of units can be derived from the base and supplementary SI units. Table 3 lists the derived units of the SI system that have special names. Many other common derived units do not have specific names; examples are velocity, measured in meters per second (m/s), and volume, measured in cubic centimeters (cm^3).

TABLE 3. SI DERIVED UNITS FROM NAMES			
Quantity	Name of derived SI unit	Symbol	Expressed in terms of base or supplementary SI units or in terms of other derived SI units
frequency	hertz	Hz	1 Hz = 1 s^{-1}
force	newton	N	1 N = 1 $kg \cdot m/s^2$
pressure, stress	pascal	Pa	1 Pa = 1 N/m^2
energy, work, quantity of heat	joule	J	1 J = N·m
power	watt	W	1 W = 1 J/s
electric charge, quantity of electricity	coulomb	C	1 C = 1 A·s
electrical potential, potential difference, tension, electromotive force	volt	V	1 V = 1 J/C
electric capacitance	farad	F	1 F = 1 C/V
electric resistance	ohm	Ω	1 Ω = 1 V/A
electric conductance	siemens	S	1 S = 1 Ω^{-1}
flux of magnetic induction, magnetic flux	weber	Wb	1 Wb = 1 V·s
magnetic flux density, magnetic induction	tesla	T	1 T = 1 Wb/m^2
inductance	henry	H	1 H = 1 Wb/A
luminous flux	lumen	lm	1 lm = 1 cd·sr
illuminance	lux	lx	1 lx = 1 lm/m^2

The prefixes given in Table 4 are an important part of the SI system. They allow any numerical value to be written as a number between 0.1 and 1000, as shown, for example, in Table 5. This may at first seem a trivial convenience, but it actually is one of the most important characteristics of the SI system. The most important prefixes in Table 4 are indicated by an asterisk. Centi (10^{-2}) is used primarily with meter to form the useful centimeter. Table 5 shows the use of these prefixes. Notice that in some cases there are two acceptable statements of the same quantity (0.325 mm and 325 μm). The kilogram is a special case. Because the name of this base unit of mass contains the name of the SI prefix "kilo," the names of the decimal multiples and submultiples of the unit of mass are formed by adding the prefixes to the word "gram." Thus, 10^{-6} kg is written as milligram (mg) instead of micro-kilogram (μkg).

TABLE 4. SI PREFIXES

Factor by which the unit is multipled	Prefix	
	Name	Symbol
10^{12}	tera	T
* 10^{9}	giga	G
* 10^{6}	mega	M
* 10^{3}	kilo	k
10^{2}	hecto	h
10	deca	da
10^{-1}	deci	d
* 10^{-2}	centi	c
* 10^{-3}	milli	m
* 10^{-6}	micro	μ
* 10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

TABLE 5. USE OF SI PREFIXES					
Quantity Expressed in Base or Derived Units		Quantity Restated in Base or Derived Units		Quantity Expressed with prefix and base of derived unit	
12000 N		12×10^{3} N		12 kN	
0.000325 m	or	0.325×10^{-3}m	or	0.325 mm	
		325×10^{-6}m		325 µm	
1401 V		1.401×10^{3} V		1.401 kV	
34200 W		34.2×10^{3} W		34.2 kW	
1.87×10^{-7} S	or	0.187×10^{-6} S	or	0.187 µs	
		187×10^{-9} S		187 ns	
3.28×10^{7} J		32.8×10^{6} J		32.8 MJ	
0.95 kg		950×10^{-3} kg		950 g	

RULES FOR WRITING SI UNITS

The following are rules for writing SI units:

- The unit symbols are written in lower case letters, except that the first letter is written in upper case when the unit is derived from a proper name.

  Examples: m meter A ampere
  s second Wb weber

- Compound units formed by the multiplication of two or more units may be written in one of the following ways:

  N•m N.m Nm.

  The first of these is most common and will be used throughout UTC to eliminate possible confusion. (Notice that mN could be read as millinewton or meter times newton if the dot indicating multiplication is not used consistently. Such ambiguity must be avoided.)

- Compound units formed by the division of one unit by another are written in the following ways:

  m/s $\frac{m}{s}$ $m \cdot s^{-1}$

  The notation s^{-1} is the same as 1/s and indicates the reciprocal of the base or derived unit.

- In no case should more than one solidus (/ as in m/s) on the same line be included in such a combination unless parentheses are included to avoid all ambiguity. Powers of units may also be used:

  Example: unacceptable — m/s/s

  acceptable — (m/s)/s m/s^2 $m \cdot s^{-2}$

- Only one prefix may be used when forming a multiple or submultiple of a base or derived unit.

  Example: unacceptable — mμm (millimicrometer)

  acceptable — nm (nanometer)

Example A shows several improper expressions written in SI units and a better statement of each quantity. Such "improper" expressions are in common use and some will probably remain so, because they are convenient in some calculations.

EXAMPLE A: WRITING QUANTITIES WITH SI UNITS

Given: The following table containing quantities expressed improperly in SI units.

Find: Proper expression for each quantity.

Solution:

Quantity Measured	Improper Expression	Proper Expression
length	2480 m	2.48 km
mass	0.00032 kg	0.32 g or 320 mg
time	6.72×10^{-5} s	67.2 μs
velocity	0.025 m/s	2.5 cm/s or 25 mm/s
energy	5500 mJ	5.5 J
acceleration	4.3×10^{3} m/s/s	4.3 km/s^2
power	2.5 kMW	2.5 GW

OTHER UNITS USED WITH SI UNITS

Certain units outside the SI system frequently are used with SI units because of their practical importance (Table 6) or because of the needs of specialized fields (Table 7). In a limited number of cases, compound units are formed from these units and SI units; for example, kg/h and km/h. Such units are not strictly part of the SI system.

TABLE 6. NON-SI UNITS USED WITH SI UNITS BECAUSE OF PRACTICAL IMPORTANCE

Quantity	Name of Unit	Unit Symbol	Definition
time	minute	min	1 min = 60 s
	hour	h	1 h = 60 min
	day	d	1 d = 24 h
plane angle	degree	°	$1° = (\pi/180)$ rad
	minute	'	$1' = (1/60)°$
	second	''	$1'' = (1/60)'$
volume	litre	l	$1\ l = 1\ dm^3$
mass	tonne	t	$1\ t = 10^3$ kg

TABLE 7. SPECIAL UNITS USED WITH SI UNITS

Quantity	Name of Unit	Unit Symbol	Definition
energy	electron-volt	eV	1 electron volt is the kinetic energy acquired by an electron in passing through potential difference of 1 volt in vacuum; $1\ eV = 1.60219 \times 10^{-19}$ J
mass of an atom	atomic mass unit	u	1 (unified) atomic mass unit is equal to the fraction 1/12 the mass of an atom of the nuclide C^{12}; $1\ u = 1{,}66053 \times 10^{-27}$ kg

length	astronomic unit	AU[1]	1 AU = 149,600 x 10^6 m (System of astronomic constants, 1964)
	parsec	pc	1 parsec is the distance at which 1 astronomic unit subtends an angle of 1 second of arc; 1 pc = 206.265 AU = 30.857 x 10^{12} m
pressure of fluid	bar[2]	bar	1 bar = 10^5 Pa

[1]This unit has no international symbol; AU is the abbreviation of the English name; the abbreviation of the French name is UA.

[2]The bar is not mentioned by CIPM in this group of units; in many countries, however, there are special requirements for this unit.

SI UNITS IN UNIFIED TECHNICAL CONCEPTS

The International System of Units is used throught Unified Technical Concepts and is itself an aid to unification. Although some examples require a detailed study of the physics involved, as in Concept Module 1-0, "Force," others illustrate unification with a minimum of explanation. The following are examples:

- In Concept Module 2-0, "Work," the unit of energy in the SI system is always the Joule (J). This unit is used to express energy in mechanical, fluid, thermal, electrical, and optical systems throughout UTC.
- In Concept Module 3-0, "Rate," all rates are expressed in SI units as some quantity divided by time in seconds. Any quantity having a denominator in seconds is a rate.
- In Concept Module 6-0, "Power," power is defined as energy divided by time, or the rate of doing work, and is measured in watts (1W = 1 J/s). This definition is true in all energy systems (mechanical, electrical, etc.)

Because of the practical nature of UTC, and because SI is not the only system of units in use today, other common units are used in UTC modules. Quantities expressed in SI units often must be converted to equivalent expressions in English units. Table 8 lists some of the more useful conversion factors. The use of these conversion factors is illustrated in Example B.

TABLE 8. CONVERSION TO SI UNITS		
Quantity	Non SI Unit	SI Equivalent
length	1 inch (in)	2.54 cm
length	1 yard (yd)	0.9144 m
force	1 pound (lb)	4.445 N
power	1 horsepower (hp)	746 W
energy	1 calorie (cal)	4.186 J

EXAMPLE B: CONVERSION TO SI UNITS

Given: The following quantities:

(a) 12 in
(b) 0.25 hp
(c) 250 cal

Find: Equivalent expressions in SI units.

Solution:

(a) $(12\ \text{in})\left(\frac{2.54\ \text{cm}}{1\ \text{in}}\right) = 30.48\ \text{cm}$

(b) $(0.25\ \text{hp})\left(\frac{746\ \text{W}}{1\ \text{hp}}\right) = 186.5\ \text{W}$

(c) $(250\ \text{cal})\left(\frac{4.186\ \text{J}}{\text{cal}}\right) = 1046.5\ \text{J} = 1.0465\ \text{kJ}$

In the SI system, the base unit of mass is the kilogram and the unit of force (N) is derived. The English system uses a base unit of force called the "pound" and a less-familiar derived mass unit called a "slug." There can be no conversion of pounds to kilograms, because the two units do not measure the same quantity. (The two systems were developed from two different arbitrary starting points.) One should remember, however, that one kilogram weighs 2.2 pounds on the earth's surface, as illustrated in Example C.

EXAMPLE C: WEIGHT OF MASS IN KILOGRAMS	
Given:	Mass of 84 kg.
Find:	Weight in pounds.
Solution:	1 kg weighs 2.2 lb
	$(84\ \text{kg})\left(\frac{2.2\ \text{lb}}{\text{kg}}\right) = 184.8\ \text{lb}$

DEFINITIONS OF SI UNITS

The exact definitions of most SI units are actually of little interest in UTC. They are given here to illustrate the precision with which they are defined and their arbitrary nature.

BASE UNITS

- Meter — The meter is the length equal to 1,650,763.73 wavelengths in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton-86 atom.
- Kilogram — The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.
- Second — The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom.
- Ampere — The ampere is that constant electric current which, if maintained in two straight, parallel conductors of infinite length, of negligible circular cross-section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per meter of length.
- Kelvin — The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.
- Mole — The mole is the amount of substance of a system that contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

- Candela — The candela is the luminous intensity, in the perpendicular direction, of a surface of 1/600,000 square meter of a black body, at the temperature of freezing platinum, under a pressure of 101,325 newtons per square meter.

SUPPLEMENTARY UNITS

- Radian — The radian is the plane angle between two radii of a circle which cut off on the circumference an arc equal in length to the radius.

- Steradian — The steradian is the solid angle which, having its vertex at the center of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere.

SUMMARY

The International System of Units (SI) is now the accepted system of measurement units throughout the world. Based largely upon the Metric System, the SI System is most important in technology. There are base units, units derived from names, and prefixes. Other units not a part of the SI System are used with it; these units include the minute, the hour, and the day.

The seven basic SI units are the meter (symbol m), kilogram (kg), second (s), ampere (A), kelvin (K), mole (mol), and candela (cd). The radian (rad) and steradian (sr) are supplementary units. Derived units include the hertz (Hz), newton (N), joule (J), watt (W), coulomb (C), volt (V), farad (F), ohm (Ω), weber (Wb), tesla (T), henry (H), lumen (lm), lux (lx), pascal (Pa), and siemens (S).

CALCULATIONS AND CONVERSIONS WITH SI UNITS

MATERIALS

Calculator (recommended but not required).

PROCEDURE

1. Use the necessary prefixes, and write the following quantities in SI units with a numerical value between 0.1 and 1000:

2.8×10^4 m	= _____	2,700,000 Ω	= _____
2.8×10^4 nm	= _____	0.0015 A	= _____
2.8×10^4 mm	= _____	0.015 cm	= _____
350,000 Hz	= _____	8.4×10^8 W	= _____
3.5×10^9 Hz	= _____	2.3×10^{-6} kg	= _____
1.45×10^{-8} s	= _____	0.04 N	= _____

2. Perform the following calculations, and express the result in proper SI notation:

82 m ÷ 16 s	= _____
55 mm ÷ 180 ms	= _____
1.36 kg ÷ 140 s	= _____
18 m/s x 480 s	= _____
5.50 kg x 16 mm/s	= _____
3.2 N x 6.5 m	= _____

3. Find the reciprocal of the following values, and express the results in proper SI notation:

t = 3 s	$\frac{1}{t}$ = _____
l = 0.15 cm	$\frac{1}{l}$ = _____
f = 60 Hz = 60 s^{-1}	$\frac{1}{f}$ = _____

4. Convert the following values to equivalent values expressed in SI notation:

0.002 in = _____
42 ft = _____
150 hp = _____
150 lb = _____
840 cal = _____
45 min = _____
0.25 l = _____

5. Calculate the weight of the following masses in pounds:

650 g wt. = _____ lb
400 kg wt. = _____ lb
160 mg wt. = _____ lb

SELF CHECK

1. Complete the following chart of SI base units:

Symbol	Name	Quantity Measured
s		
kg		
mol		
A		
cd		
K		
m		

2. List the quantity measured and the symbol for the following SI supplementary units:

Radian.
Steradian.

3. Complete the following chart of SI derived units:

Symbol	Name	Quantity Measured
W		
J		
Hz		
N		
V		
Ω		
C		

4. State the symbol and the multiple of ten indicated by each of these prefixes:

Milli.
Micro.
Centi.
Mega.
Giga.
Kilo.
Nano.

5. Write the following quantities in proper SI notation:

4876000 Ω.

0.0027 cm.

1440 mW.

5.2×10^4 g.

0.055 ms.

6. Perform the following calculations, and write the answers in proper SI notation:

15 m/s ÷ 8 s = _____.

650 kg x 3.2 m/s = _____.

0.28 kg ÷ 30 x = _____.

7. Name a non-SI unit that may be used with SI units for measuring the following quantities:

Time.
Volume.
Plane Angle.
Mass.

8. Convert these lengths to SI units:

   16 ft.
   27.5 in.
   0.025 in.

9. Calculate the weight in pounds of the following masses:

   15 kg.
   350 g.

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APPENDIX E

CONCEPT MODULE SUMMARY CHARTS

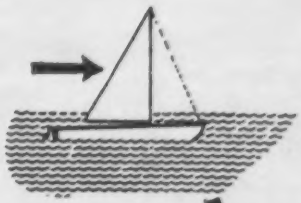
CONCEPT 1 - 0

FORCE

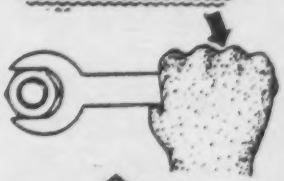
FORCELIKE QUANTITIES CAUSE MOVEMENT OF MASS, CHARGE OR ENERGY

MECHANICAL

TRANSLATIONAL: FORCE CAUSES LINEAR DISPLACEMENT OF MASS



ROTATIONAL: TORQUE CAUSES ANGULAR DISPLACEMENT OF MASS



FLUIDAL

PRESSURE DIFFERENCE CAUSES DISPLACEMENT OF VOLUME OF FLUID

ELECTRICAL

POTENTIAL DIFFERENCE CAUSES DISPLACEMENT OF CHARGE

THERMAL

TEMPERATURE DIFFERENCE CAUSES DISPLACEMENT OF HEAT ENERGY

CONCEPT 2 - 0

WORK

WORK RESULTS WHEN A FORCELIKE QUANTITY CAUSES A DISPLACEMENT.
THE UNIFYING EQUATION FOR WORK IS –
WORK DONE = ENERGY TRANSFERRED
WORK = FORCELIKE QUANTITY x DISPLACEMENTLIKE QUANTITY

MECHANICAL

TRANSLATIONAL: WORK = FORCE x DISPLACEMENT

ROTATIONAL: WORK = TORQUE x ANGLE OF ROTATION

FLUIDAL

WORK = PRESSURE DIFFERENCE x FLUID VOLUME DISPLACED

ELECTRICAL

WORK = POTENTIAL DIFFERENCE x CHARGE TRANSFERRED

THERMAL

HEAT ENERGY TRANSFERRED TO AN OBJECT
WHEN TEMPERATURE INCREASES:
HEAT ENERGY = TEMPERATURE CHANGE x HEAT CAPACITY

CONCEPT 3 - 0

RATE

RATE IS THE RATIO OF THE CHANGE IN A DISPLACEMENTLIKE QUANTITY TO THE TIME REQUIRED FOR THAT CHANGE.
THE UNIFYING EQUATION FOR RATE IS -

$$\text{RATE} = \frac{\text{DISPLACEMENTLIKE QUANTITY}}{\text{ELAPSED TIME}}$$

MECHANICAL

TRANSLATIONAL

$$\text{VELOCITY} = \frac{\text{DISPLACEMENT}}{\text{ELAPSED TIME}}$$

$$\text{ACCELERATION} = \frac{\text{CHANGE IN VELOCITY}}{\text{ELAPSED TIME}}$$

ROTATIONAL

$$\text{ANGULAR VELOCITY} = \frac{\text{ANGULAR DISPLACEMENT}}{\text{ELAPSED TIME}}$$

$$\text{ANGULAR ACCELERATION} = \frac{\text{CHANGE IN ANGULAR VELOCITY}}{\text{ELAPSED TIME}}$$

FLUIDAL

$$\text{VOLUME FLOW RATE} = \frac{\text{VOLUME DISPLACED}}{\text{ELAPSED TIME}}$$

$$\text{MASS FLOW RATE} = \frac{\text{MASS DISPLACED}}{\text{ELAPSED TIME}}$$

ELECTRICAL

$$\text{CURRENT} = \frac{\text{CHARGE TRANSFERRED}}{\text{ELAPSED TIME}}$$

THERMAL

$$\text{HEAT FLOW RATE} = \frac{\text{HEAT ENERGY TRANSFERRED}}{\text{ELAPSED TIME}}$$

CONCEPT 4 - 0

MOMENTUM

MOMENTUM DESCRIBES THE TENDENCY OF MOVING MASS TO CONTINUE ITS MOTION WITHOUT CHANGE UNLESS A FORCELIKE QUANTITY ACTS UPON IT. IMPULSE IS THE PRODUCT OF THE FORCELIKE QUANTITY AND THE TIME DURING WHICH IT ACTS. THE UNIFYING EQUATIONS FOR IMPULSE AND MOMENTUM ARE -

MOMENTUM = INERTIA X RATE
IMPULSE = FORCELIKE QUANTITY X ELAPSED TIME
IMPULSE = CHANGE IN MOMENTUM

MECHANICAL

TRANSLATIONAL

MOMENTUM = MASS x VELOCITY

IMPULSE = FORCE x TIME

ROTATIONAL

ANGULAR MOMENTUM = MOMENT OF INERTIA x ANGULAR VELOCITY

ANGULAR IMPULSE = TORQUE x TIME

FLUIDAL

MOMENTUM = MASS x VELOCITY

THE CONCEPT OF MOMENTUM IS NOT APPLIED TO ELECTRICAL OR THERMAL SYSTEMS

CONCEPT 5 - 0

RESISTANCE

RESISTANCE IS AN OPPOSITION TO MOTION AND CAUSES MOTION TO EVENTUALLY CEASE IF NO FORCELIKE QUANTITIES ARE PRESENT TO SUSTAIN IT.

MECHANICAL

UNLIKE OTHER FORMS OF RESISTANCE, FRICTION IS NOT DEPENDENT UPON RATE.

FRICTIONAL FORCE = COEFFICIENT OF FRICTION X NORMAL FORCE

THE UNIFYING EQUATION FOR OTHER TYPES OF RESISTANCE IS-

$$\text{RESISTANCE} = \frac{\text{FORCELIKE QUANTITY}}{\text{RATE}}$$

FLUIDAL

$$\text{RESISTANCE} = \frac{\text{PRESSURE DIFFERENCE}}{\text{FLOW RATE}}$$

ELECTRICAL

$$\text{RESISTANCE} = \frac{\text{VOLTAGE}}{\text{CURRENT}}$$

THERMAL

$$\text{RESISTANCE} = \frac{\text{TEMPERATURE DIFFERENCE}}{\text{HEAT FLOW RATE}}$$

THE ENERGY USED TO OVERCOME RESISTANCE IN MECHANICAL, FLUIDAL, AND ELECTRICAL SYSTEMS IS CONVERTED INTO HEAT

CONCEPT 6 - 0

POWER

POWER IS THE RATE OF DOING WORK. THE UNIFYING EQUATIONS OF POWER ARE-

$$\text{POWER} = \frac{\text{WORK (ENERGY)}}{\text{TIME ELAPSED}} \quad \text{OR} \quad \text{POWER} = \text{FORCELIKE QUANTITY} \times \text{RATE}$$

MECHANICAL

TRANSLATIONAL:

$$\text{POWER} = \frac{\text{MECHANICAL WORK}}{\text{TIME}}$$

$$\text{POWER} = \text{FORCE} \times \text{VELOCITY}$$

ROTATIONAL:

$$\text{POWER} = \frac{\text{MECHANICAL WORK}}{\text{TIME}}$$

$$\text{POWER} = \text{TORQUE} \times \text{ANGULAR VELOCITY}$$

FLUIDAL

$$\text{POWER} = \frac{\text{FLUIDAL WORK}}{\text{TIME}}$$

$$\text{POWER} = \text{PRESSURE} \times \text{FLOW RATE}$$

ELECTRICAL

$$\text{POWER} = \frac{\text{ELECTRICAL WORK}}{\text{TIME}}$$

$$\text{POWER} = \text{VOLTAGE} \times \text{CURRENT}$$

THERMAL

$$\text{POWER} = \frac{\text{HEAT ENERGY}}{\text{TIME}}$$

CONCEPT 7 - 0

POTENTIAL AND KINETIC ENERGY

POTENTIAL ENERGY IS THE ENERGY OF POSITION. KINETIC ENERGY IS THE ENERGY OF MOVING MASS. THE FOLLOWING ARE EXAMPLES OF POTENTIAL AND KINETIC ENERGY:

MECHANICAL

POTENTIAL ENERGY

GRAVITATIONAL: $E_p = mgh$

SPRING: $E_p = 1/2\ kx^2$

KINETIC ENERGY

TRANSLATIONAL: $E_K = 1/2\ mv^2$

ROTATIONAL $E_K = 1/2\ I\omega^2$

FLUIDAL

GRAVITATIONAL POTENTIAL ENERGY $E_p = (\rho V)gh$

KINETIC ENERGY $E_K = 1/2\ (\rho V)v^2$

ELECTRICAL

POTENTIAL ENERGY STORED IN A CAPACITOR $E_p = 1/2\ CV^2$

THERMAL

THERMAL ENERGY IS THE KINETIC ENERGY OF MOVING MOLECULES

THE PRINCIPLE OF CONSERVATION OF ENERGY STATES THAT THE FORM OF ENERGY MAY BE CHANGED BUT ENERGY CAN BE NEITHER CREATED NOR DESTROYED. THE TOTAL ENERGY OF A CLOSED SYSTEM IS CONSTANT.

CONCEPT 8 - 0

FORCE TRANSFORMERS

FORCE TRANSFORMERS ARE DEVICES THAT TRANSFORM FORCELIKE QUANTITIES AND DISPLACEMENTLIKE QUANTITIES. THE UNIFYING EQUATION FOR FORCE TRANSFORMERS IS-

ENERGY IN = ENERGY OUT

OR

INPUT FORCELIKE QUANTITY x INPUT DISPLACEMENTLIKE QUANTITY = OUTPUT FORCELIKE QUANTITY x OUTPUT DISPLACEMENTLIKE QUANTITY

MECHANICAL

TRANSLATIONAL: FORCE IN x DISPLACEMENT IN = FORCE OUT x DISPLACEMENT OUT

ROTATIONAL: TORQUE IN x ANGULAR DISPLACEMENT IN = TORQUE OUT x ANGULAR DISPLACEMENT OUT

FLUIDAL

FORCE IN x DISPLACEMENT IN =
FORCE OUT x DISPLACEMENT OUT

ELECTRICAL

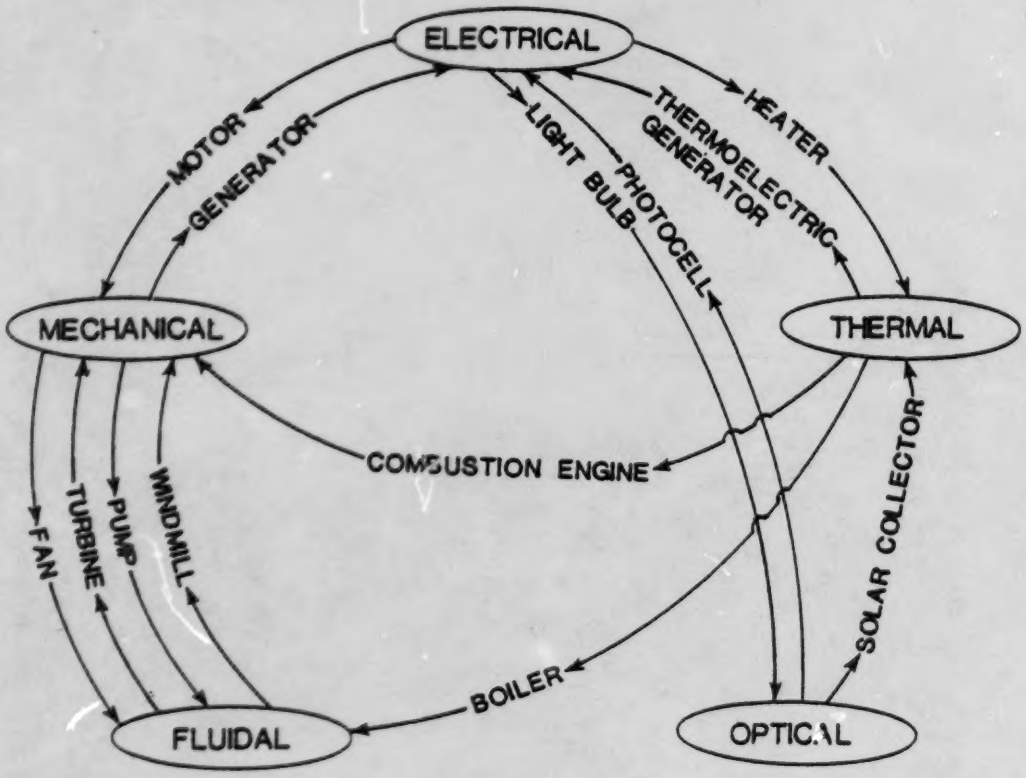
VOLTAGE IN x CURRENT IN =
VOLTAGE OUT x CURRENT OUT

THE CONCEPT OF FORCE TRANSFORMERS IS NOT APPLIED TO THERMAL SYSTEMS.

CONCEPT 9 - 0

ENERGY CONVERTORS

ENERGY CONVERTORS ARE DEVICES THAT CHANGE ENERGY IN ONE FORM (ENERGY SYSTEM) TO ENERGY IN ANOTHER FORM.

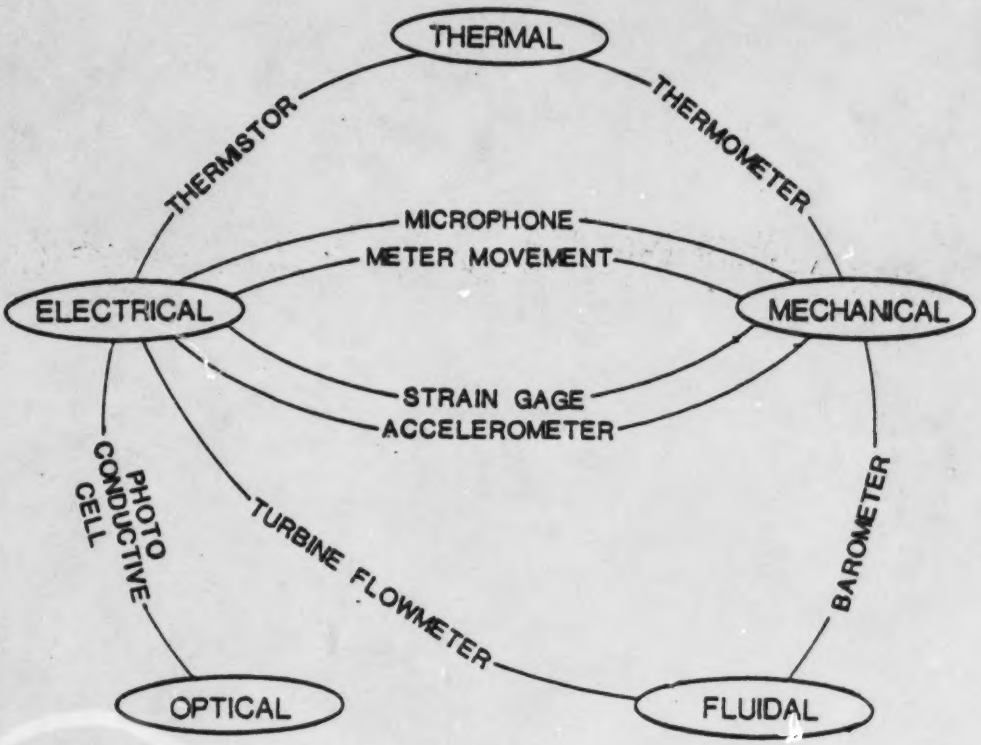


ALL ENERGY CONVERTORS CHANGE A PART OF THE INPUT ENERGY TO WASTE HEAT.

CONCEPT 10 - 0

TRANSDUCERS

TRANSDUCERS ARE DEVICES THAT CONVERT INFORMATION-CARRYING SIGNALS FROM ONE ENERGY SYSTEM TO ANOTHER. MOST TRANSDUCERS PRODUCE PRODUCE ELECTRICAL OR MECHANICAL OUTPUTS.



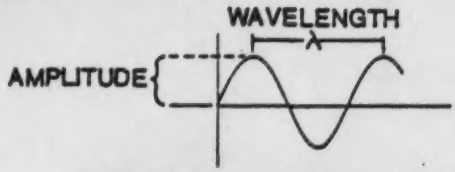
CONCEPT 11 - 0

VIBRATIONS AND WAVES

A WAVE IS A DISTURBANCE IN WHICH ENERGY IS TRANSMITTED FROM ONE LOCATION TO ANOTHER.

VELOCITY $v = \lambda/T$

$v \quad \lambda f$



PERIOD: T = TIME FOR ONE CYCLE

FREQUENCY: F = NUMBER OF CYCLES IN ONE SECOND

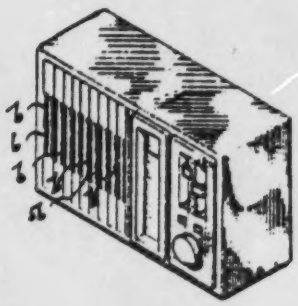
THE FOLLOWING ARE EXAMPLES OF WAVES:

MECHANICAL

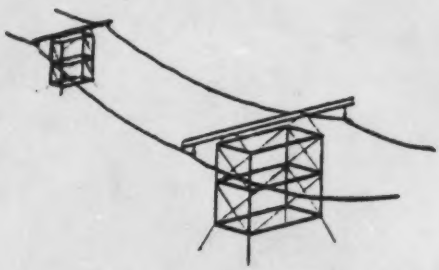
VIBRATIONS

FLUIDAL

SOUND



ELECTRICAL



A.C. POWER

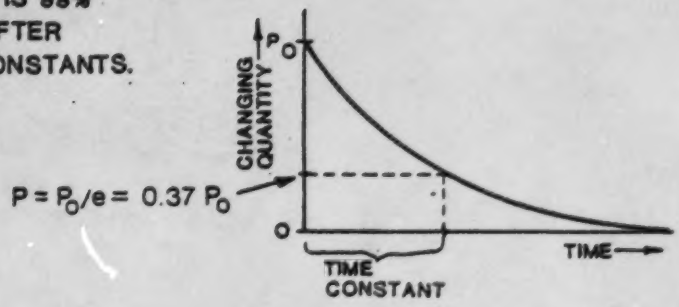
OPTICAL

LIGHT

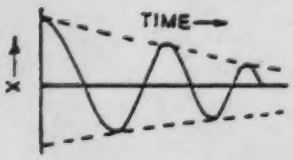
CONCEPT 12 - 0

TIME CONSTANTS

WHEN A PHYSICAL SYSTEM IS CHANGING WITH TIME BUT IS APPROACHING A STEADY STATE, RATES IN THAT SYSTEM DIMINISH EXPOTENTIALLY. THE TIME CONSTANT OF THE SYSTEM IS THE TIME REQUIRED FOR THE CHANGE TO BE 63% COMPLETE. THE CHANGE IS 99% COMPLETE AFTER FIVE TIME CONSTANTS.

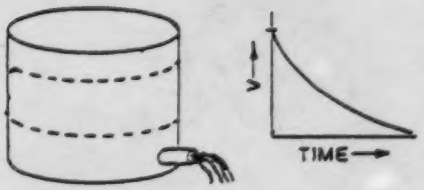


MECHANICAL

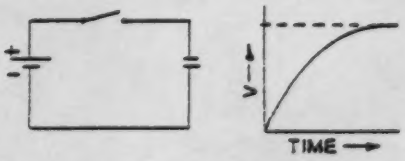


DAMPED OSCILLATIONS

FLUIDAL

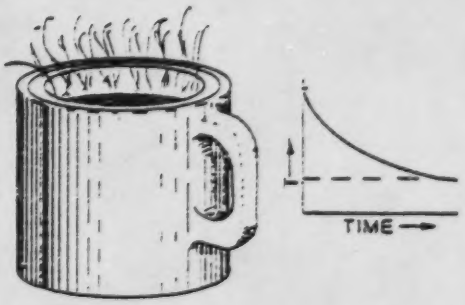


ELECTRICAL



CHARGING CAPACITORS

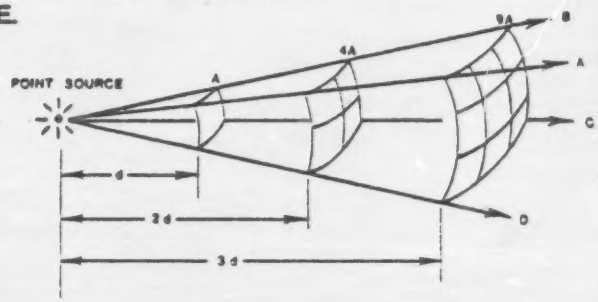
THERMAL



CONCEPT 13 - 0

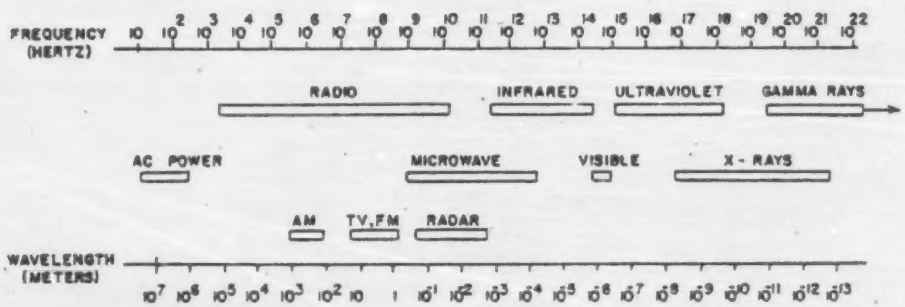
RADIATION

RADIATION IS THE PROCESS BY WHICH ENERGY MOVES AWAY FROM A SOURCE IN A STRAIGHT LINE. THE INVERSE SQUARE LAW STATES THAT THE INTENSITY OF RADIATION AT ANY POINT IS INVERSELY PROPORTIONAL TO THE SQUARE OF THE DISTANCE FROM THE SOURCE.



TWO TYPES OF PHENOMENA ARE OFTEN CLASSED AS "RADIATION"

ELECTROMAGNETIC RADIATION



PARTICLE RADIATION

RADIOACTIVE ATOMS MAY RELEASE TWO TYPES OF PARTICLES WHEN THEY DECAY. ALPHA PARTICLES CONSIST OF TWO PROTONS AND TWO NEUTRONS-A HELIUM NUCLEUS. BETA PARTICLES ARE ENERGETIC ELECTRONS EJECTED FROM THE NUCLEUS.

APPENDIX F

EVALUATION REPORT OF PROJECT CONSULTANTS/EDITORS

EVALUATION REPORT OF PROJECT CONSULTANTS/EDITORS

June 3, 1980

Daniel M. Hull, President
Center for Occupational
Research and Development
4800 Lakewood Drive
Waco TX 76.10

Dear Dan

After editing nearly 200 UTC concept and application modules, it seems appropriate that we, your editors, reflect our overall reaction to the UTC philosophy in general and to the modules in particular.

A methodology of teaching which presents the important principles of physics in a unified format is highly desirable. Historically physics principles have been presented within the traditional divisions of mechanics, heat, sound, wave motion, electricity and magnetism, optics, and modern physics. Many excellent physics texts have been — and still are — organized along these divisions. One consequence of such a division of subject matter may be the "compartmentalization" of physics which is created in the mind of the student. Rather than viewing a principle of physics as a powerful tool which applies across many disciplines and sub-divisions — surely the goal of every textbook and teacher — there is a real danger that the student will learn the principle as it applies only in mechanics, or in wave motion, or in thermodynamics. He may not come to appreciate the true generality of its application in other related or different disciplines.

Unified Technical Concepts (in physics) is organized and structured to avoid such tunnel vision. Rather than treating the principles of physics as they arise in the traditional disciplines of mechanics, heat, sound, etc., UTC physics focuses on a principle and then illustrates its applicability in all of the major energy systems — mechanical, thermal, electrical and fluidal. This method of organization, presentation and reinforcement impresses the student with the unification of important physical concepts. It prepares him to think outside of traditional compartments. For example, the student comes to appreciate the concept of force in the motion of fluids, the transfer of heat, and the movement of electric current, as well as in the movement of mass, where it is normally introduced. In short, UTC physics provides the student with the essential principles of physics, stresses their unification, and enables the student to apply them efficiently to a host of apparently unrelated, diverse engineering problems.

Such has been the philosophy underlying the methodology of UTC physics -- a unification of concepts in flexibly packaged modules. And to a large extent, as field testing has indicated, this innovative experiment has been successful. But there still remain problems and room for improvement.

a. The unification concept works ideally with some physics principles (force, energy, rate, resistance power) and not so well with others (momentum, optics, radiation). For examples, it is unnatural to speak of momentum as a unifying concept in thermal and electrical systems where momentum, as a concept, does not arise.

b. Also, a single concept, such as displacement, might be unified meaningfully in the energy systems of mechanics, electricity and fluids, but have limited applicability in heat systems.

So while ideal in perception, the desire to unify all principles across all energy systems cannot always be realized. This requires that valid disclaimers be pointed out in the reading material. It requires also that the teacher, whose task it is to emphasize unification, identify those few areas where unification is not practical.

Since we have edited each of the nearly 200 modules, the following comments on technical content and organization of the modules may be appropriate.

a. Uniformity in technical presentation and style of writing is generally lacking when many authors contribute to a "textbook." This was, in fact, our single, largest problem. Our principal goal was to verify the technical content, but, our principal task, as it turned out, involved substantial rewriting, and rephrasing to achieve some uniformity in technical style and expression. With all our efforts, however, we feel that we fell somewhat short of the standards defined for the project. In several instances, major rewriting would have been necessary to achieve the uniform quality and system we all desired.

b. The self-check/exercises at the end of the modules were treated in a rather cavalier manner by several authors. Rather than create meaningful questions and problems, the self-checks and exercises were often little more than restated objectives. (I understand that, where possible, this is being corrected by adding challenging, meaningful problems and self-checks.)

c. Perhaps it is unavoidable when so many authors contribute to modules which cover so comprehensive a matrix as does UTC, but we discovered unnecessary duplication of ideas and experiments. This was especially true in heat transfer. At least five or six modules covered the ideas of thermal energy transfer by conduction, convection, and radiation. The only way to avoid unnecessary duplication is to lay out the entire course carefully at the outset and insist that authors follow the prescribed guidelines.

d. Inevitably, when reducing the principal concepts of physics to twelve or thirteen, as we have done, and then reinforcing them with application modules, many supportive principles of physics are left out. In order to correct this deficiency, application modules are then written to fill this void. But these are not true application modules; rather they are concept support modules. Consequently the organizational logic of concept/application modules is somewhat weakened.

But with all of its shortcomings - which in reality are neither numerous nor serious, UTC physics is a bold, innovative reorganization of physics. In our judgment it has its greatest promise in programs where physics is taken only once - in technical schools and high school vocational programs, for example. With enthusiastic instructor support (absolutely essential) it can be made superior to traditional physics courses as a learning experience for those students who are taking physics for the first time, and who do not intend to pursue physics or engineering, per se, at the university level. Its concentration on unification, real world examples, and hands-on experience should leave the vocational/technical school student with a good feeling toward physics. And most importantly, it should prepare him to use physics as a powerful tool in the analysis of diverse engineering problems, those he will cope with now and those he will cope with in the new technologies of tomorrow.

We should learn a great deal from the technical institute faculties who are presently field testing UTC physics. It may be a worthwhile experience (and a shot in the arm to physics courses in high schools) to introduce and field test the UTC physics program in several selected high schools. We encourage you to look into this.

Sincerely

Leno S Pedrotti

LENO S. PEDROTTI
Chief Technical Editor
Department of Physics
Air Force Institute
of Technology

Frank L. Pedrotti, S.J.

FRANK L. PEDROTTI, S.J.
Associate Technical Editor
Department of Physics
Marquette University

APPENDIX G

UTC PILOT TESTING IN INSTITUTIONS

MODULE EVALUATION FORM - TERC 101A

PLEASE RETURN THIS FORM AT THE COMPLETION OF THE FIRST MODULE USED.

TERC/UTC
LUBE/JW
OCTOBER 17, 1977

GENERAL INFORMATION ABOUT YOU, YOUR STUDENTS, AND YOUR COURSE

Thank you for consenting to use the Unified Technical Concepts (UTC) modules in your course. Without your assistance these materials would not have a reason for existence. Please take a couple of minutes and complete this form so we might become better acquainted with you and your course.

1.

Your Name and School -

2.

Instructor Data	*Industrial*	*Related Military*	*Teaching*
Years of experience			
Degrees or certificates			
Related Training			

3.

Your Course Data						
Number of students						
Age range						
Students' majors						
% of class with previous physics courses		*100*	*75*	*50*	*25*	*0*

4.

Course Data	*Hours per week*	*Number of weeks*
A. *Lecture*		
B. *Lab*		
C. *Prerequisites for course*		
D. *Supplemental materials used*		

5. *What other aspects of your use of the modules could cause differences in student achievement? (For example: Small lab, equipment shortage, scheduling problems, etc.)*

MODULE EVALUATION FORM - TERC 102A

MODULE NUMBER OR TITLE _____

PLEASE RETURN THIS FORM AT THE COMPLETION OF THE MODULE LISTED.

TERC/UTC
LUBE/JW
OCTOBER 17, 1977

Your experiences in using this module are necessary for us to revise and improve the content to increase its effectiveness. Please assist us by showing how the module affected your course.

1. *Were the following parts of the module appropriate?*

Module Part	Yes	No	Needs improving by:
Objectives			
Illustrations			
Experimental procedures			
Example problems			
Content level			
Time needed to complete			
Other Part(s)			

2. *What were the basic reactions to the module?*

	Enthusiastic	Interested	Neutral	Confused	Opposed
A. The students					
B. By you, the instructor(s)					

3. *How effective was this module in helping the student reach the objectives?*

Very Effective	Effective	Slightly Effective	Ineffective	Totally Confusing

4. *Using this module my students improved their comprehension of the physics principles involved.*

A Great Deal	Quite A Bit	Some	Very Little	None

5. *Some schools might find parts of the module inappropriate for their use. Did you find this true in your course? If so, please explain what parts were not appropriate for your use and why not? (Please continue on reverse side.)*

_____

_____

6. *Do you have any general suggestions for the improvement of this module? Please continue on the reverse side.)*

_____

_____

_____

TERC/UTC
LUBE/GP
10-28-77

MODULE EVALUATION FORM - TERC 103A

STUDENT EVALUATION

THE LEARNING MATERIALS YOU HAVE BEEN USING ARE IN THEIR INITIAL STAGE OF DEVELOPMENT. WITH YOUR HELP THEY WILL BE IMPROVED THROUGH THE REVISIONS YOU SUGGEST BY RESPONDING TO EACH OF THESE STATEMENTS.

1. *I have/have not (circle one) used modules before, and I enjoyed using these.*

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

2. *Learning from modules is better than learning from the usual texts and materials.*

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

3. *By using these modules, I feel that my knowledge of Physics was increased about*

100%	80%	60%	40%	20%

4. *The objectives in the modules were easily understood and helpful to me.*

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

5. *If a friend were going to take a similar course, I would recommend one in which modules were used in the same way my instructor used them in this course.*

Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree

6. *The part of the modules I found most useful was the (check one)*

Introduction	Prerequisites	Objectives	Discussion
Materials	Procedures	Exercises	None

7. *If I were to change one part of these modules it would be the (check one)*

Introduction	Prerequisites	Objectives	Discussion
Materials	Procedures	Exercises	None

The reason I would change this part is _____

_____

_____

UNIFIED TECHNICAL CONCEPTS

COURSE DESIGN FOR

ENERGY CONSERVATION-AND-USE TECHNICIANS

QUARTER SYSTEM

The number of UTC application modules recommended for the Energy Conservation-and-Use Technician curriculum are listed in the table below by concept module number and quarter. Concepts are listed in the order recommended to meet prerequisites for other courses in the ECUT curriculum.

Quarter	Concept Number	Essential Application Modules	Optional Application Modules	Total
First (UTC I)	1-0	8	2	10
	2-0	4	0	4
	3-0	6	0	6
	5-0	8	4	12
Quarter Totals		26	6	32
Second (UTC II)	6-0	5	2	7
	11-0	4	5	9
	7-0	3	3	6
	9-0	3	10	13
Quarter Totals		15	20	35
Third (UTC III)	8-0	3	2	5
	10-0	6	2	8
	12-0	3	2	5
	13-0	5	7	12
Quarter Totals		17	13	30
Total		58	39	97

UNIFIED TECHNICAL CONCEPTS

COURSE DESIGN FOR

ENERGY CONSERVATION-AND-USE TECHNICIANS

SEMESTER SYSTEM

The number of UTC application modules recommended for Energy Conservation-and-Use Technician curriculum are listed in the table below by concept module number and semester. Concepts are listed in the order recommended to meet prerequisites for other courses in the ECUT curriculum.

Semester	Concept Number	Essential Application Modules	Optional Application Modules	Total
First (UTC I)	1-0	8	2	10
	2-0	4	0	4
	3-0	6	0	6
	5-0	8	4	12
	6-0	4	2	6
	11-0	4	5	9
Semester Totals		34	13	47
Second (UTC II)	7-0	3	3	6
	9-0	3	10	13
	8-0	3	2	5
	10-0	6	2	8
	12-0	2	2	4
	13-0	5	7	12
Semester Totals		22	26	48
Total		56	39	95

UNIFIED TECHNICAL CONCEPTS
MODULE SELECTION FOR
ENERGY CONSERVATION-AND-USE TECHNICIAN

Unified Technical Concepts is a flexible physics instructional system consisting of 191 modules designed to meet the needs of a number of technologies. The TERC-SW staff has determined that the following modules are best suited for use in the Energy Conservation-and-Use Technician curriculum. Those application modules preceeded by an asterisk are considered essential. Other application modules listed are optional. TERC-SW recommends that UTC courses for Energy Technicians include the 56 "essential" application modules and a selection of additional "optional" modules chosen to meet the needs, schedules and budgets of individual schools.

* Essential application modules.

1-0 Force

* 1M2 Addition of Mechanical Forces
* 1M3 Addition of Torques
  1M6 Tension in Wires and Cables
* 1F1 Atmospheric Pressure
* 1F2 Density, Buoyance and Specific Gravity
  1F4 Manometers
* 1E3 Electric Forces and Fields
* 1E4 Magnetic Forces and Fields
* 1T1 Thermometers
* 1T2 Temperature Difference and Heat Flow

2-0 Work

* 2M2 Work Done by a Winch
* 2F1 Work Done by a Water Pump
* 2T1 Heat Energy Required for a Temperature Increase
* 2T4 Fundamentals of Air Conditioning

3-0 Rate

* 3M2 Velocity at Constant Acceleration
* 3M3 Displacement at Constant Acceleration
* 3M5 Rotational Motion
* 3E1 Electric Current
* 3E2 Frequency
* 3T2 Rate of Heat Conduction

5-0 RESISTANCE

* 5M2 Effect of Lubricants
5M3 Rolling Friction
* 5F2 Viscosity
* 5F3 Fluid Resistance in Pipes
5F4 Valves and Regulators
* 5E1 Ohm's Law
* 5E2 Series and Parallel Resistors
5E4 Conductors, Semiconductors and Insulators
5E5 Resistance of Wires
* 5E6 Resistance of Semiconductor Junction
5E8 Volt-Ohm-Milliammeter
* 5T2 Heat Flow Through Insulation

6-0 Power

* 6M2 Prony Brake
* 6F1 Hydraulic Power
* 6E1 Electrical Power Measurement
6E3 Efficiency of Electric Motors and Generators
6E4 Electrical Power Consumption
* 6T1 Heat Exchangers

7-0 Potential and Kinetic Energy

7M3 Rotational Kinetic Energy of a Flywheel
* 7F2 Venturi Meters
7F3 Pitot Tubes
* 7E2 Energy Stored in a Capacitor
* 7E3 Energy Stored in an Inductor
7E4 Series and Parallel Capacitors

8-0 Force Transformers

8M1 Levers
* 8M3 Drive Systems
8M4 Gear Trains
* 8F1 Hydraulic Press
* 8E1 Electrical Transformers

9-0 Energy Convertors

9F1 Turbines
9F2 Fluid Pumps
9F3 Wind Power
9F4 Fans and Blowers
9F5 Vacuum Pumps
* 9E1 Electric Generators
9E2 Alternators
* 9E3 Electric Motors
9E4 Solenoids and Relays

9-0 Cont'd

*	9E5	Photovoltaic Materials
	9T1	Boilers
	9T2	Thermoelectric Generators
	9T3	Solar Collectors

10-0 Transducers

*	10M1	Strain Gages
	10M2	Accelerometers
*	10F1	Bourdon Tubes
	10F5	Vacuum Gages
*	10E1	Meter Movements
*	10T2	Bimetallic Strips
*	10T3	Temperature Measuring Devices
*	10T5	Thermistors

11-0 Vibrations and Waves

	11M3	Vibration Isolation
*	11M4	Resonance
*	11F1	Cavity Vibrations and Standing Waves
	11F5	Pressure Measurement of Sound Waves
*	11E1	Alternating Voltage and Current
	11E2	Phase Relationships in AC Circuits
	11E3	Oscilloscope
*	11E4	Rectifiers
	11E5	Electronic Filtering in DC Power Supplies

12-0 Time Constants

	12F1	Rate of Emptying Tanks
*	12E1	RC Circuits
	12T1	Response Time of Thermocouples
*	12T2	Time Constants of Heating and Cooling

13-0 Radiation

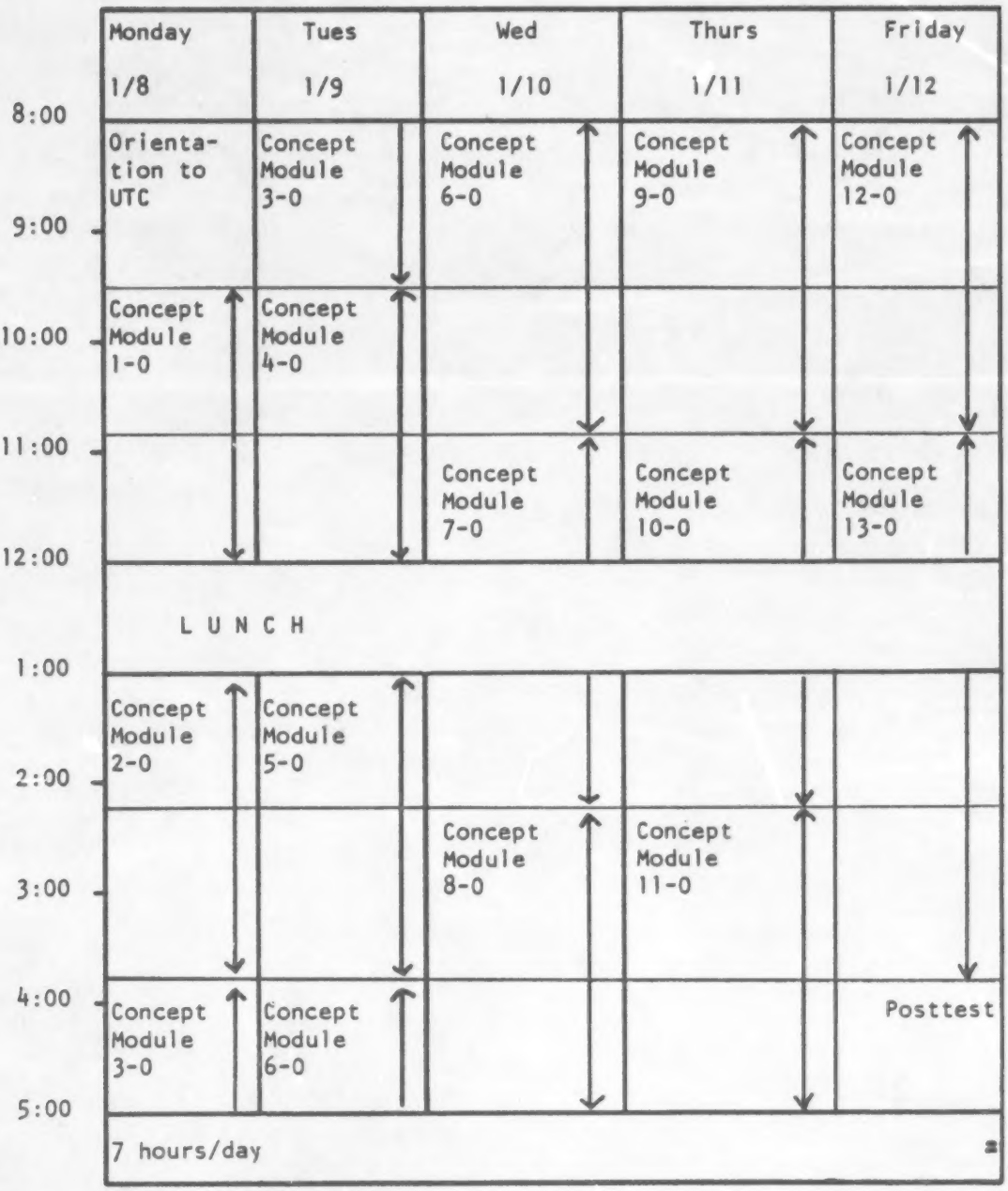
*	13L1	Inverse Square Law - Spreading of Light
*	13L2	The Optical Spectrum
*	13L3	Light Sources
	13L4	Lasers
	13L5	Stroboscopes - Light Pulses
	13L6	Optical Filters - Absorption of Light
	13L7	Specular and Diffuse Reflection of Light
	13L8	Image Formation with Mirrors
	13L9	Prisms - Refraction and Dispersion of Light
	13L10	Lenses - Focusing and Spreading of Light
*	13L16	Infrared Radiation Thermometers
*	13L17	Illumination

APPENDIX H

UTC SHORT COURSE FOR EMPLOYED TECHNICIANS AT LOS ALAMOS SCIENTIFIC LABORATORY

UTC SHORT COURSE FOR EMPLOYED
TECHNICIANS AT LOS ALAMOS SCIENTIFIC LABORATORY

SCHEDULE



Class Schedule

15 min. breaks at 9:30, 10:45, 2:15 and 3:45.

TERC-SW/UTC
JJ/pt
12/7/78

UNIFIED TECHNICAL CONCEPTS

PRETEST

INSTRUCTIONS: Select the correct answer for each question and place an X in the corresponding circle on the answer sheet provided.

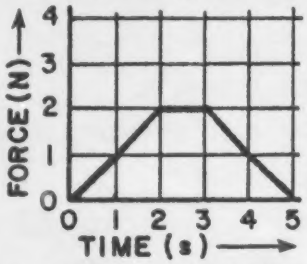
1. A torque of 24 ft•lb is to be applied to a bolt but a torque wrench is not available. The wrench used has a length of 8 inches. How much force must be applied perpendicular to the wrench handle to produce the desired torque?
   a. 36 lb.
   b. 192 lb.
   c. 3 lb.
   d. 16 lb.

2. A metal cylinder with a mass of 12 kg is acted upon by a force of 4 N. What is the resulting acceleration?
   a. 3 m/s^2.
   b. 48 m/s^2.
   c. 0.33 m/s^2.
   d. 1.73 m/s^2.

3. An automobile traveling at 10 m/s begins to slow with a deceleration of 0.25 m/s^2. How much time is required to reach a velocity of 5 m/s?
   a. 20 s.
   b. 1.25 s.
   c. 40 s.
   d. 2.5 s.

4. A fluid pressure of 40 psi produces a laminar flow through a pipe at 2.4 gal/min. What will the flow rate be if the pressure is reduced to 30 psi?
   a. 3.2 gal/min.
   b. 1.2 gal/min.
   c. 1.8 gal/min.
   d. 0.68 gal/min.

5. The graph shows the force acting on a body as a function of time. The body has a mass of 10 kg and was initially at rest. What is its velocity at the end of 5 s?



a. 6 m/s.
b. 5 m/s.
c. 2 m/s.
d. 0.6 m/s.

6. A force of 8 lb is required to slide a metal plate weighing 32 lb across a flat surface. How much force will be required to move the plate if a box weighing 80 lb is placed upon it?

a. 20 lb.
b. 52 lb.
c. 112 lb.
d. 28 lb.

7. A voltage of 1500 V is placed across a 22 kΩ resistor and a 33 kΩ resistor in series. What is the resulting current?

a. 114 mA.
b. 49.5 mA.
c. 68.2 mA.
d. 27.3 mA.

8. Water (62.4 lb/ft^3) must be pumped to a height of 16 ft to fill a 200 ft^3 tank in 5 min. What is the horsepower of the pump required? (1 hp = 550 $\frac{ft \cdot lb}{s}$).

a. 6.05 hp.
b. 665.6 hp.
c. 1.21 hp.
d. 72.6 hp.

9. An electric motor runs at 1200 RPM and develops a torque of 140 ft·lb. What is the power of the motor?

a. 5.09 hp.
b. 1.62 hp.
c. 305.4 hp.
d. 0.60 hp.

10. 2.5 liters of water is heated from 25°C to 85°C in 18 min. What is the power consumption of the electric heating element used? (1 cal = 4.186J).

a. 34.9 kw.
b. 2.43 kw.
c. 1046 w.
d. 581 w.

11. An elevator car weighs 1200 lb and contains a load of 875 lb. It travels a vertical distance of 36 ft in 16 s. What is the horsepower of the motor?

a. 135.84 hp.
b. 3.58 hp.
c. 8.49 hp.
d. 4.91 hp.

12. An electric motor produces 0.25 hp and has an efficiency of 81%. The motor runs on a 110 V a.c. circuit. What is the current through the motor? (1 hp = 746 W).

a. 0.48 A.
b. 1.70 A.
c. 1.37 A.
d. 2.09 A.

13. A disk with a mass of 10 kg and a radius of 35 cm rotates at 1800 RPM and has a rotational kinetic energy of 14J. What rotational rate will be necessary to produce a rotational kinetic energy of 28J?

a. 2546 RPM.
b. 3600 RPM.
c. 2800 RPM.
d. 3247 RPM.

14. A 4.2 kg liquid sample is heated from 3°C to 28°C by the addition of 87.7 kilocalories. What is the specific heat of the liquid?

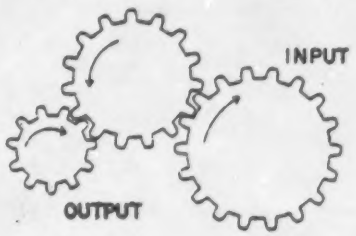
a. 0.970.
b. 1.20.
c. 0.877.
d. 0.835.

15. 1.5 kJ of energy is to be stored in a capacitor. The desired voltage is 1000 V. What size capacitor must be used?

a. 54.7 μf.
b. 1500 μf.
c. 3000 μf.
d. 3000 mf.

16. The input shaft of the gear train shown rotates at 1.7 rad/s and produces a torque of 6 N·m. What is the rotational rate of the output shart?

a. 0.96 rad/s.
b. 2.78 rad/s.
c. 1.04 rad/s.
d. 0.76 rad/s.



17. An electrical transformer is designed to produce a secondary voltage of 880 V when 120 V is applied to the primary. What is the output voltage if the transformer is connected backwards with 120 V applied to the secondary?

a. 880 V.
b. 6453 V.
c. 53.7 V.
d. 10.36 V.

18. A hydraulic jack has an input cylinder diameter of 0.5 in and an output cylinder diameter of 1.25 in. What is the output force when the input force is 35 lb?

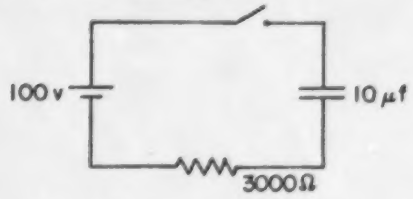
a. 87.5 lb.
b. 14.0 lb.
c. 218.75 lb.
d. 43.75 lb.

19. When one piece of optical filter material is placed in a 2 mW helium-neon laser beam, the transmitted power is 1.5 mW. What will the transmitted power be if two additional identical filters are added?

a. 0.84 mW.
b. 0.50 mW.
c. 0.75 mW.
d. 0.03125 mW.

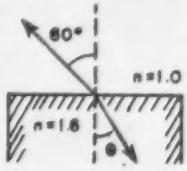
20. If the capacitor in the figure is initially fully discharged when the switch is closed, approximately how much time will be required for the capacitor voltage to reach 99 V?

a. 30 ms.
b. 150 ms.
c. 30 μs.
d. 15 ms.



21. What is the angle of refraction θ in the following diagram?

a. 28.9°.
b. 32.7°.
c. 37.5°.
d. 57.2°.



22. A microwave source produces radiation with a frequency of 25 GHz. What is the wavelength? ($C = 3 \times 10^8$ m/s).

a. 83.3 m.
b. 12 m.
c. 1.2 cm.
d. 8.3 cm.

23. A light source produces an irradiance of 380 mW/cm^2 at a distance of 12 m. What will the irradiance be at 36 m?

a. 42.2 mW/cm^2.
b. 127 mW/cm^2.
c. 380 mW/cm^2.
d. 1.14 W/cm^2.

24. A resonant cavity for microwaves has a length of 3.4 cm. What is the lowest frequency that can form a standing wave in the cavity?

a. 8.82 GHz.
b. 4.41 GHz.
c. 2.20 GHz.
d. 8.82 MHz.

25. Two light waves of equal intensity I arrive at a screen 180° out of phase. The resulting intensity on the screen is:

a. 2I
b. I^2
c. $\frac{\pi I^2}{2}$
d. 0

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UTC PRETEST ANSWER SHEET

Example: (a) (b) (X) (d)

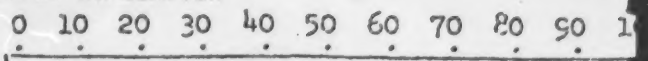
Employee Number _____

1. (a) (b) (c) (d)
2. (a) (b) (c) (d)
3. (a) (b) (c) (d)
4. (a) (b) (c) (d)
5. (a) (b) (c) (d)
6. (a) (b) (c) (d)
7. (a) (b) (c) (d)
8. (a) (b) (c) (d)
9. (a) (b) (c) (d)
10. (a) (b) (c) (d)
11. (a) (b) (c) (d)
12. (a) (b) (c) (d)
13. (a) (b) (c) (d)
14. (a) (b) (c) (d)
15. (a) (b) (c) (d)
16. (a) (b) (c) (d)
17. (a) (b) (c) (d)
18. (a) (b) (c) (d)
19. (a) (b) (c) (d)
20. (a) (b) (c) (d)
21. (a) (b) (c) (d)
22. (a) (b) (c) (d)
23. (a) (b) (c) (d)
24. (a) (b) (c) (d)
25. (a) (b) (c) (d)

LASL SHORT COURSE

DATA ON Unified Technical Concepts
January 8 - 12, 1979

STUDENT/EMPLOYER EVALUATION



I. CONCERNING YOU-THE STUDENT

1. I met my learning goals.
   a) Strongly agree — 5%
   b) Agree — 65%
   c) Neutral — 25%
   d) Disagree — 5%
   e) Strongly disagree

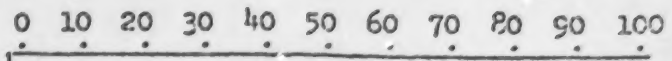
2. Having taken this course will positively affect my attitude when I return to work.
   a) Strongly agree — 15%
   b) Agree — 60%
   c) Neutral — 15%
   d) Disagree — 10%
   e) Strongly disagree

3. I can do my job better, having taken this course.
   a) Strongly agree — 5%
   b) Agree — 65%
   c) Neutral — 20%
   d) Disagree — 10%
   e) Strongly disagree

4. I can be more useful to my work group because I took this course.
   a) Strongly agree — 15%
   b) Agree — 75%
   c) Neutral
   d) Disagree — 10%
   e) Strongly disagree

5. Taking this course has helped my professional growth.
   a) Strongly agree — 15%
   b) Agree — 65%
   c) Neutral — 15%
   d) Disagree — 5%
   e) Strongly disagree

6. Taking this course has helped my personal growth.
   a) Strongly agree — 15%
   b) Agree — 70%
   c) Neutral — 15%
   d) Disagree
   e) Strongly disagree



CONCERNING THE INSTRUCTOR
J. Jones

7. Has command of subject.
   a) Strongly agree — 40%
   b) Agree — 60%
   c) Neutral
   d) Disagree
   e) Strongly disagree

8. Is an effective communicator.
   a) Strongly agree — 55%
   b) Agree — 45%
   c) Neutral
   d) Disagree
   e) Strongly disagree

9. Gears course material to achieving stated objectives.
   a) Strongly agree — 20%
   b) Agree — 65%
   c) Neutral — 10%
   d) Disagree
   e) Strongly disagree
   f) No Comment — 5%

10. Understands and answers questions well.
   a) Strongly agree — 50%
   b) Agree — 50%
   c) Neutral
   d) Disagree
   e) Strongly disagree

11. Tailors course material to LASL employees.
   a) Strongly agree — 25%
   b) Agree — 30%
   c) Neutral — 25%
   d) Disagree — 15%
   e) Strongly disagree
   f) No Comment — 5%

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12. Changing the instructor, but not the content, would improve the quality of this course.
   a) Strongly agree — 5%
   b) Agree
   c) Neutral — 5%
   d) Disagree — 45%
   e) Strongly disagree — 40%
   f) No Comment — 5%

III. CONCERNING THE COURSE

13. Content is logically organized.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

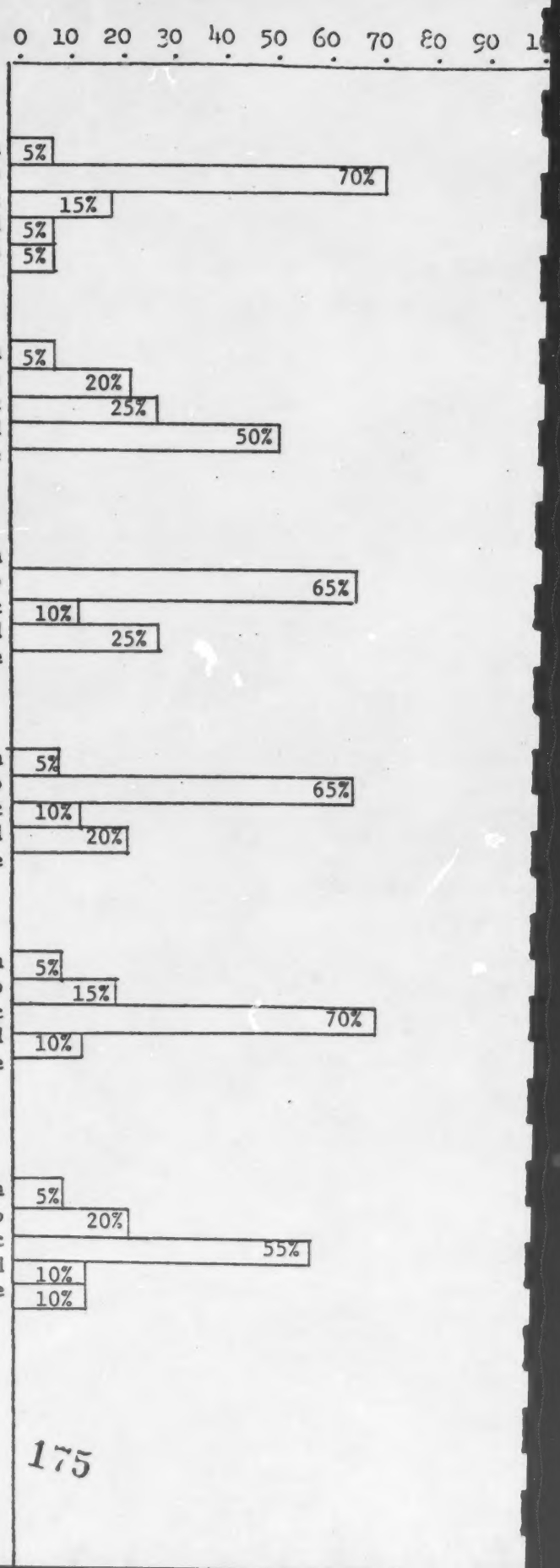
14. Content is hard to comprehend.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

15. Depth of topic coverage is good.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

16. Breadth of topic coverage is good.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

17. Reading assignments are well chosen.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

18. Length of reading assignments is reasonable.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

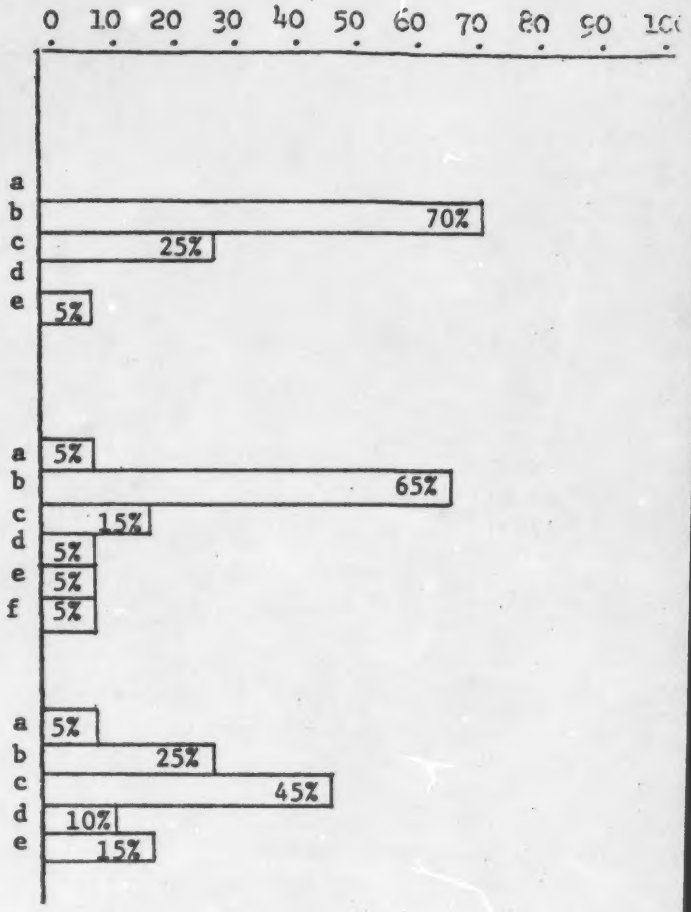


CONCERNING FACILITIES/LEARNING ENVIRONMENT

19. The chance to learn about the practical application of theory is given.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly Disagree

20. Class exercises significantly helped learning.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly Disagree
    f) No Comment

21. Enough "hands on" learning experiences are provided to practice skills.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree



V. CONCERNING ADMINISTRATION OF CONTINUING EDUCATION PROGRAMS.

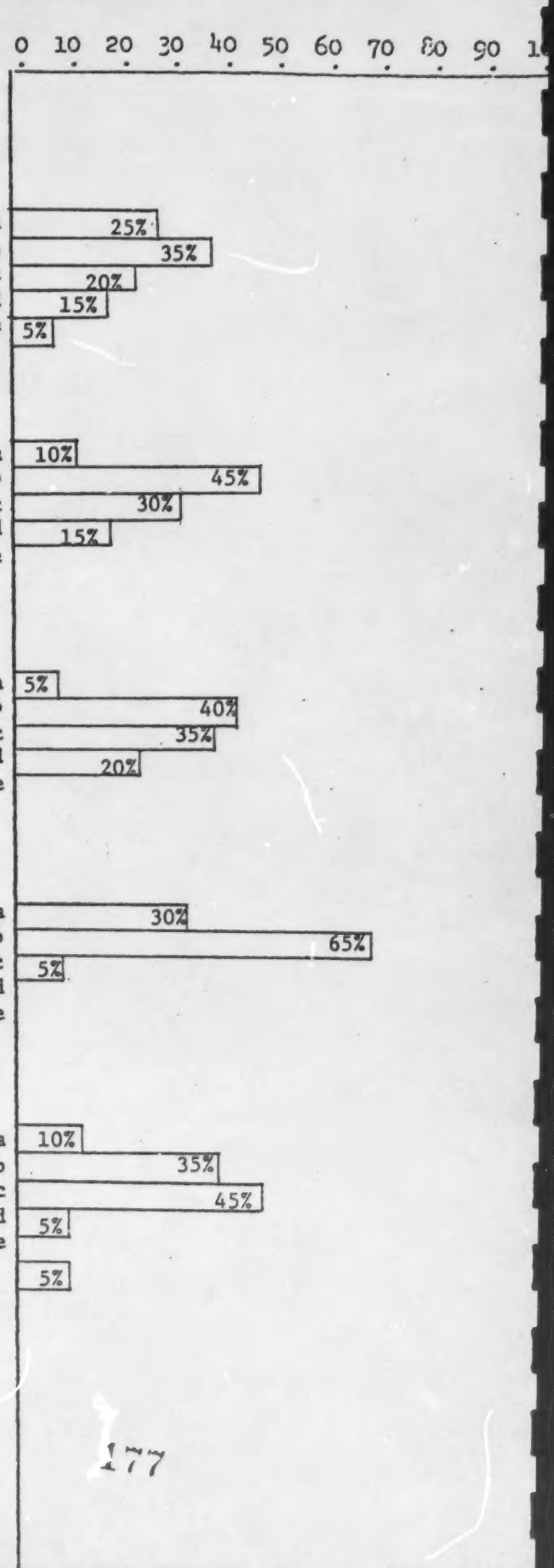
22. The registration process for courses is efficient.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

23. Courses like this one, but on a more advanced level, need to be offered.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

24. Courses like this one, but on a more elementary level, need to be offered.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

25. More employee development courses need to be offered.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree

26. More management courses need to be offered.
    a) Strongly agree
    b) Agree
    c) Neutral
    d) Disagree
    e) Strongly disagree



UNIFIED TECHNICAL CONCEPTS SHORT COURSE
TO RETRAIN EMPLOYED TECHNICIANS

LOS ALAMOS SCIENTIFIC LABORATORY (LASL)
January 8 through 12, 1979

LASL Comments, Criticisms, and Suggestions:

1. This course covers a lot of material in a short time, which makes cramming necessary and interfers with learning, especially if the student has no previous physics. This is a good refresher course, especially the concept of Unifying concepts. This is something that was never covered in any of the previous physics courses I've taken. The instructor strayed from the course outline at times, which is probably more of a benefit than a hindrance. The instructor was able to answer questions satisfactorily without having to go back to the text, which shows a good understanding of Physics.

2. First of all, the idea is excellent. All tools of principle used by any technician are directly or indirectly derived from physics. To offer a hard-nosed to-the-point summary of all of physics, to show the origin of these ideas, and to fill the gaps is even more useful than might be obvious at first. The U.T.C. approach is very good. The only real question any technician asks is, given a set of conditions, what will happen next? The U.T.C. idea of boiling things down into forces, masses, and motion and applying this across all the major areas of physics makes new insights into the basic question of "If I do this, what will happen?" possible.

   For criticisms: It would better without a text. Substitute comphehensive reference book (written for the course), in an outline form for the lesson plans with tables of conversions and summaries of formulas. Also, two topics should have been included: A) Gas Laws (Pressure/Volume Ratios, etc.) and B) AC Electrical Theory (especially power factor, etc.).

   Personality of the instructor plays an important part in the success of this type of truncation of material and John Sonen does an excellent job. The class was a hugh success, but a less talented instructor might have caused a disaster with the same material.

3. The instructor was very good in explaining concepts. Course material was conceived and presented in a clear manner. Material is probably not of much use in my present position (Chem Tech II in geochemistry), but should prove valuable in the future.

4. As a review of college physics, I found the class quite valuable; however, for people with little or no previous physics there would be little benefit. The presentation was excellent and this is critical to a course of this nature. The application of this course to LASL techs in their everyday work is minimal. We simply are not called on to calculate things of this nature with the exception of electrical calculation.

5. As compared to other courses taken in the past, the Unified Technical Concepts course was one-thousand percent more satisfying. I believe with the class instruction, the demonstrations, and the literature distributed I can now understand, and,in some instances,be able to analyze some of the problems which I encounter in my daily work. The level that the course was presented, I feel most technicians can benefit from; however, there is a considerable amount of reading and learning for a one week course, which I feel should be spread out over a longer period of time to allow for all the reading (learning different units), or have the book distributed a couple of weeks prior to the class.

6. I feel that the instructor did a very good job in explaining this course. He was very patient and tried very hard to present this course at a tech level. It would have been a big help if we had received the workbooks ahead of time. For example, the first day we had to work on three modules, not knowing what was coming up next. I enjoyed the course and feel it has prepared me to work more effectively at my present job.

7. I was, at first, skeptical about this course for the following reasons: 1) It proposed to cover more ground than could reasonably be done justice in one week; and, 2) I was certain that I would learn nothing that I had not learned in one year of college physics.

   My second concern proved valid, yet the course was presented in a way that seemed to accommodate those that already knew the material as well as those of us who knew the material to review without falling asleep,but not too quick for someone who had not been exposed to physics.

   Most importantly, however, I was impressed with the modular organization of the text. As outlined by the thirteen modules, the subject could be covered in any depth, from a brief overview to a full year's academic course. Conceivably, this material could be presented in: 1) a brief, purely conceptual outline for non-technical employees (administrative, clerical, etc.) who must interface with technical employees; 2) a not so brief outline with mathematical application of specifics (much as the course was presented this week) for technicians with no prior physics course work; and 3) in depth courses in mechanics, fluid mechanics, vacuum systems, heat, electrical theory, optics, etc. for technicians that have the basic course work and need more detailed knowledge in a specific discipline.

   On the negative side, the pre- and post-tests may well provide less than accurate indications. For one thing, the pre-test ruled out the use of any reference works (requiring a mental recall of nearly a decade on my part). How well the UTC will <u>aid</u> the memory will not be shown in the post-test, however, as that test is taken in the same week that the material is presented. Further, the pre-test had some errors and ambiguities that will not likely be found on the post-test. Also, the text is riddled with grammatical and typographical errors, a condition that would be intolerable in the finished product. Finally, the course should be presented in a facility capable of accommodating its needs. The facility at the College of Santa Fe, while blessed with a few nice touches, proved to be woefully inadequate.

   In summary, the course definitely has merit and I was pleasantly surprised to learn as much.

8. My first reactions after hearing about the course were mixed, however, after having spent a week in the course, it has changed my initial thoughts. The idea behind the "unified" approach is indeed helpful and can be applied to many areas of my work. My job includes work with fluids, electrical, thermal, mechanical, and optical problem solving, all of which were discussed in the unified approach.

   My experience in college with physics instruction has consisted of two semesters. The physics presented in the UTC course touched on many of the basic physics principles that I was exposed to in my two semesters of college physics-related courses. I feel if I had not had this exposure to the above courses this would have been a very long week. In the future, people who consider attending this course should be knowledgeable of basic algebra and some prior knowledge of basic physics principles. A very basic physics pretest might be a consideration. This trend of thought is reflected from the amount of work and ideas crammed in one short week.

   I feel the UTC program will be a very useful tool for technicians at LASL, once the approach and course outline have been streamlined.

9. Having worked at the Meson Facility, I find that this course has been very beneficial. This course was superior to other similar courses, but I do feel a lot of the matter covered will not be applicable. I believe this course will be beneficial to beginning techs, because of the insight one gains from this course. I would like to see more emphasis put on the units with more examples of their use, e.g. microns and angstroms used for foil thickness measurements.

10. Repeat course time should be a minimum of two weeks. I feel there is too much to learn in just one week, especially with all the concepts introduced. The course content was excellent and practical, and I feel the "Unification" approach is excellent. Demonstrations were adequate for a course of this duration, but more time and some "hands-on" application would definitely be needed. For any technician at my level, a prerequisite in algrbra and plane geometry would be highly advised prior to this course, especially since it is so condensed. I would like to take this course again but on a time period of two quarters, a semester, or a tri-semester. The text is well done and will be extremely useful for self study to improve one's knowledge of basic physics and for a bibliographical reference.

11. I have a lot of experience as an electronics tech, but have little instruction in theory, and have never had a physics course or instruction in metric units, which I think should be a prerequisite for this course, as I was so bogged down with terms and formulas, I didn't get a chance to learn them as well as I would have liked, or should have. I did learn a few things, but the class was too condensed to learn all the concepts. As a refresher course, for one with high school physics background, this would have been ideal.

    The instructor was good, however, if he had gone by the book closer, it would have been easier to follow his thoughts. However, the book was difficult to follow at times.

    It would be helpful if one could recieve the text book ahead of class by a week or two, with instructions to read as much as possible ahead of time.

    Examples in the book are given in both metric and British units, instructions also. Would it be possible to use one system and have a section in the book explaining how to convert when necessary?

    A short pamphlet on conversion between the British and Metric measures

and how they apply to physics, along with basic physics formulas would have been nice to have a few weeks in advance of the course.

12. The material covered in the course is very good. Forty hours is about the right amount of time for the course, but should be spread out over a longer period of time than just one week, so one would be able to absorb the material properly. The course is very helpful as far as my job is concerned.

13. Material covered thru noon Wednesday should have constituted an entire course, with more opportunity to do problems. Could not absorb material presented Wednesday afternoon and Thursday, consequently forgot most of the formulas presented before then. Presentation and demonstrations were excellent. There is not much need for "hands-on" lab work because most of us are already familiar with labs. The amount of lab demonstrations presented was good. "Unifying concepts" should have been stressed more, with more basic ideas and less applications work because the real value of the course is basic concepts. The material presented was at the right level for my background.

14. Johnny Jones is an excellent instructor, who is very qualified to teach this particular subject. He makes learning fun. The text book is okay. The facilities were great after the phone problems were resolved. Having class members of various backgrounds was excellent, as we were able to learn from them as well. The demonstrations were very pertinent and enjoyable. I feel the class needs to be longer, so one will have time for all the required reading and to do the problems.

    I am a Chem Tech, but do laser work, Mechanical Tech work, etc.; I feel this would be very beneficial to my fellow techs.

    The test at the end of the class should be open book with notes, as it is difficult to memorize all the material through the period of one week.

    We could have advanced more rapidly, and easier also, if we had the texts in advance of the first day of class.

15. Excellent course, except forty hours is inadequate to assimilate the material. Five 8-hour days is just too much--extend the course to at least sixty hours, about four hours a day, so one will be able to comprehend all that is required. We had NO "hands-on" experience, which would be possible if the class were extended. Jones is a must to teach this course. In general, it is a great course--just too quick.

16. I feel the course material covered was fine. I would like to see the text, used in coordination with the class, be disbursed about a week or so in advance of the class, as it is impossible to keep up with the required reading, the assignments, and the reviewing of the class notes with the pace progressing so rapidly. I feel the class would have to be twice as long if the text is not mailed in advance. An index would be very helpful with the text. The visual aids were excellent.

17. It would have been nice to have recieved the "workbook" in advance of the first day of class, as one would have time to review. The index could be more apparent for a quick guide to specific names such as "torque-p.lx," etc. I am pleased with our instructor. He was serious with his work, made some pointedly serious efforts to pass on information-- yet he realized he was on a time schedule, pleasing personality too.

    I enjoyed it very much going back to school, it was a wonderful opportunity. Thank you for everything including the coffee, choclate, etc.

18. I was and still am very grateful for the opportunity to be involved with this pilot program offering of the course. I feel that the material offered is real good, but that unless a student has a real good mathematical background, and has had a physics course before, he would find the course too intense, too condensed in terms of time. The course should be spread out over a longer span of time and more class hours should be allowed to permit the student to fully absorb the material at a slower pace. I did benefit from the course, but feel that I missed a lot, because of my minds' inability to relate to unfamiliar conditions and text materials.

UNIVERSITY OF CALIFORNIA
LOS ALAMOS SCIENTIFIC LABORATORY
PERSONNEL DEPARTMENT
P.O. Box 1663
Los Alamos, New Mexico 87545

January 18, 1979

Mr. Johnny Jones
Technical Education
Research Center
4201 Lake Shore Drive
Suite III
Waco, Texas 76710

Dear Johnny:

Thank you for doing such an excellent job with the UTC pilot course recently. The adjective I used, I'm sure, will be substantiated by the course evaluation results, which are presently being tabulated. Hopefully, by the time I have received the pre and post test results from you, the course evaluations will be ready for me to send to you. In addition, I'll send you the comments from the several observers who sat in at various times during the couse.

As for the photos I took, let's both hope the photographer took all the variables into consideration and had control over them. At this point, I'm reluctant to promise you any negatives, proofs, etc., because I really don't know how they'll turn out; however, I will let you know.

It was a pleasure working with you and I hope I have the opportunity to work with you in the future.

Sincerely,

Maria M. Wolff
Training Specialist
PER-5, MS-589

MMW/cg
0020L
cy: Dan Hull, General Manager, TERC
PER-5 File (2)

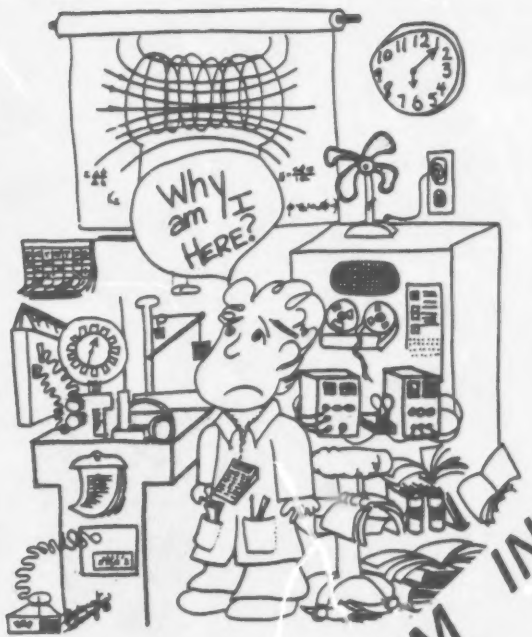
APPENDIX I

DISSEMINATION DOCUMENTS

UTC

UNIFIED TECHNICAL CONCEPTS

PHYSICS FOR THE TECHNICAL STUDENT



DOES THIS FACE [illegible] AMILIAR?

Complex modern equip[illegible]an contains mechanical, fluidal, electrical a[illegible]ermal subsystems. Consequently, the modern te[illegible]ician must understand not only these separate subsystems but also their interrelationships and the roles they play in the integrated system. Technicians need a thorough understanding of basic, applied physics that is difficult to provide with the limited time and resources available in many technical curriculums, and their knowledge must be well-organized and relevant to their specific technologies. It's a tough problem, but now there is a new approach.

Unified Technical Concepts is a flexible, modularized, hands-on instructional system designed to provide the technical student with the maximum useful physics skills in the minimum time. It consists of 191 modules, each based on behavioral objectives, from which the instructor "shops" to construct courses unique to the needs of individual technologies. Physics programs with a duration of one quarter to one year may be designed to serve areas as diverse as Automotive Mechanics and Laser Optics.

UTC incorporates both SI and English units as they are commonly used in modern technology and stresses practical application of physics skills and a "systems approach" in solving common technological problems. UTC utilizes "standard" physics laboratory equipment, such as force tables and air tracks, when appropriate but relies more heavily on the use of "real world" equipment such as shock absorbers, phonograph turntables, electric motors, and residential insulating materials. Experiments have been designed with economy in mind and low-cost alternatives are often suggested. (Two styrofoam cups make a useful calorimeter.)

COMPONENTS OF THE U T C INSTRUCTIONAL SYSTEM

Each o[illegible]. 13 CONCEPT MODULES describes [illegible]sic concept of physics and its application in fo[illegible]rgy systems" - Mechanical, Fluidal, Electrical [illegible]. Concept modules are designed for classro[illegible]ntation and include practical examples an[illegible]rations. They are the backbone of the UTC [illegible]ional system.

Each of 170 AP[illegible]ICATION[illegible] describes the application of a single phys[illegible].ciple in a single energy system. Applicatio[illegible], are designed for laboratory use and incl[illegible] a dis[illegible]ussion of the physics involved and a [illegible]y experiment performed by the student. Som[illegible] basic ph[illegible]sics (3M4 Velocity at Constant Ac[illegible]on) while others stress specific applicati[illegible] Heat Exchangers).

8 SUP[illegible].RY MODULES are designed to strengthen ma[illegible] and laboratory skills in areas such as s[illegible] graphing, logarithms, dimensional analysis [illegible]ic trigonometry.

INSTRUCTOR'S GUIDE describes effective alternatives for presenting UTC. It contains information on course design, module descriptions, equipment lists, solutions to exercises, and "helpful hints" compiled from field tests.

A STUDENT BROCHURE and an INTRODUCTION TO UTC orient the student to the UTC approach and stress "physics as a useful tool."

U T C CONCEPT MODULES

1-0	FORCE
2-0	WORK
3-0	RATE
4-0	MOMENTUM
5-0	RESISTANCE
6-0	POWER
7-0	POTENTIAL AND KINETIC ENERGY
8-0	FORCE TRANSFORMERS
9-0	ENERGY CONVERTORS
10-0	TRANSDUCERS
11-0	VIBRATIONS AND WAVES
12-0	TIME CONSTANTS
13-0	RADIATION

Unified Technical Concepts was developed by Technical Education Research Center - Southwest through a grant from the U.S. Office of Education. Materials development was guided by an Advisory Committee composed of representatives from industry and technical education. UTC materials have been field tested at four schools and revised in accordance with test results.

For additional information contact:

UTC Coordinator
Technical Education Research Center - Southwest
4201 Lake Shore Drive
Waco, TX 76710
(817) 772-8756

PROGRAM INFORMATION BROCHURE

UNIFIED TECHNICAL CONCEPTS

SUPPLEMENTARY MODULES

- S1 Formula Interpretation
- S2 International System of Units
- S3 Logarithms and Exponents
- S4 Angles and Triangles
- S5 Vectors and Scalars
- S6 Dimensional Analysis
- S7 Reading and Drawing Graphs
- S8 Precision, Accuracy, and Measurement

CONCEPT AND APPLICATION MODULES

1-0 FORCE
- 1M1 Gravity
- 1M2 Addition of Mechanical Forces
- 1M3 Addition of Torques
- 1M4 Mechanical Equilibrium in Structures
- 1M5 Stress and Strain
- 1M6 Tension in Wires and Cables
- 1F1 Atmospheric Pressure
- 1F2 Density, Buoyancy, and Specific Gravity
- 1F3 Hydraulic Jack
- 1F4 Manometers
- 1E1 Potential Difference and Charge Flow
- 1E2 Series and Parallel Voltage Sources
- 1E3 Electric Forces and Fields
- 1E4 Magnetic Forces and Fields
- 1E5 Lead-Acid Storage Battery
- 1T1 Thermometers
- 1T2 Temperature Difference and Heat Flow
- 1T3 Thermal Stress

2-0 WORK
- 2M1 Work Done on an Elevator
- 2M2 Work Done by a Winch
- 2F1 Work Done by a Water Pump
- 2F2 Work Done by a Hydraulic Lift
- 2T1 Heat Energy Required for a Temperature Increase
- 2T2 Heat Energy Required for Melting
- 2T3 Heat Energy Required for Boiling
- 2T4 Fundamentals of Air Conditioning

3-0 RATE
- 3M1 Graphic Approach to Linear Motion
- 3M2 Velocity at Constant Acceleration
- 3M3 Displacement at Constant Acceleration
- 3M4 Acceleration of a Mass by Constant Force
- 3M5 Rotational Motion
- 3M6 Radial Acceleration and Centripetal Force
- 3F1 Flow Rate Measurement with a Venturi Meter
- 3E1 Electric Current
- 3E2 Frequency
- 3T1 Heating and Cooling Rate
- 3T2 Rate of Heat Conduction

4-0 MOMENTUM
- 4M1 Angular Momentum of a Flywheel
- 4M2 Impulse and Momentum
- 4M3 Conservation of Momentum in Collisions
- 4M4 Gyroscopes
- 4F1 Rocket Engines

5-0 RESISTANCE
- 5M1 Static and Sliding Friction
- 5M2 Effect of Lubricants
- 5M3 Rolling Friction
- 5F1 Laminar and Turbulent Flow
- 5F2 Viscosity
- 5F3 Fluid Resistance in Pipes
- 5F4 Valves and Regulators
- 5F5 Shock Absorbers
- 5F6 Drag-Resistance to Motion Through Fluids
- 5E1 Ohm's Law
- 5E2 Series and Parallel Resistors
- 5E3 Internal Resistance of a Battery
- 5E4 Conductors, Semiconductors, and Insulators
- 5E5 Resistance of Wires
- 5E6 Resistance of Semiconductor Junctions
- 5E7 Resistance of Gas Laser Tubes
- 5E8 Volt-Ohm Milliammeter
- 5T1 Thermal Conductivity
- 5T2 Heat Flow Through Insulation

6-0 POWER
- 6M1 Horsepower
- 6M2 Prony Brake
- 6F1 Hydraulic Power
- 6E1 Electrical Power Measurement
- 6E2 Electric Heater
- 6E3 Efficiency of Electric Motors and Generators
- 6E4 Electrical Power Consumption
- 6T1 Heat Exchangers

7-0 POTENTIAL AND KINETIC ENERGY
- 7M1 Piledriver
- 7M2 Potential Energy of a Spring
- 7M3 Rotational Kinetic Energy of a Flywheel
- 7M4 Conservation of Energy in Collisions
- 7M5 Kinetic Energy and Horsepower of an Automobile
- 7F1 Energy Stored in Large Tanks
- 7F2 Venturi Meters
- 7F3 Pitot Tubes
- 7F4 Energy Conversion in Fluid Systems
- 7F5 Gas Laws
- 7F6 Siphons
- 7E1 Energy Stored in a Battery
- 7E2 Energy Stored in a Capacitor
- 7E3 Energy Stored in an Inductor
- 7E4 Series and Parallel Capacitors
- 7T1 Heat Storage Systems
- 7T2 Electrical Equivalent of Heat
- 7T3 Mechanical Equivalent of Heat
- 7T4 Thermal Drying
- 7T5 Mixing Liquids at Different Temperatures

8-0 FORCE TRANSFORMERS
- 8M1 Levers
- 8M2 Wedges and Inclined Planes
- 8M3 Drive Systems
- 8M4 Gear Trains
- 8M5 Block and Tackle
- 8M6 Differential Hoist
- 8F1 Hydraulic Press
- 8E1 Electrical Transformers

9-0 ENERGY CONVERTORS
- 9F1 Turbines
- 9F2 Fluid Pumps
- 9F3 Wind Power
- 9F4 Fans and Blowers
- 9F5 Vacuum Pumps
- 9E1 Electric Generators
- 9E2 Alternators
- 9E3 Electric Motors
- 9E4 Solenoids and Relays
- 9E5 Photovoltaic Materials
- 9T1 Boilers
- 9T2 Thermoelectric Generators
- 9T3 Solar Collectors

10-0 TRANSDUCERS
- 10M1 Strain Gages
- 10M2 Accelerometers
- 10F1 Bourdon Tubes
- 10F2 Aneroid Barometers
- 10F3 Differential Pressure Transducers
- 10F4 Fluid-Flow Measuring Devices
- 10F5 Vacuum Gages
- 10E1 Meter Movements
- 10T1 Automobile Thermostats
- 10T2 Bimetallic Strips
- 10T3 Temperature Measuring Devices
- 10T4 Thermocouples
- 10T5 Thermistors
- 10T6 Pyrometers

11-0 VIBRATIONS AND WAVES
- 11M1 Speed of Sound in Materials
- 11M2 Reflection and Absorption of Sound Energy
- 11M3 Vibration Isolation
- 11M4 Resonance
- 11M5 Sound Speakers
- 11F1 Cavity Vibrations and Standing Waves
- 11F2 Speaker Enclosures
- 11F3 Reverberation Time
- 11F4 Doppler Effect
- 11F5 Pressure Measurement of Sound Waves
- 11E1 Alternating Voltage and Current
- 11E2 Phase Relationships in AC Circuits
- 11E3 Oscilloscope
- 11E4 Rectifiers
- 11E5 Electronic Filtering in DC Power Supplies
- 11E6 Electronic Filtering for Frequency Selection
- 11E7 Modulation of Electrical Waves

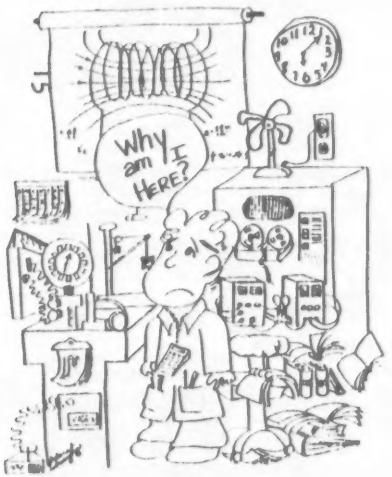
12-0 TIME CONSTANTS
- 12M1 Shock Isolation by Absorbers
- 12F1 Rate of Emptying Tanks
- 12E1 RC Circuits
- 12E2 RL Circuits
- 12E3 RLC Circuits
- 12T1 Response Time of Thermocouples
- 12T2 Time Constants of Heating and Cooling

13-0 RADIATION
- 13L1 Inverse Square Law — Spreading of Light
- 13L2 The Optical Spectrum
- 13L3 Light Sources
- 13L4 Lasers
- 13L5 Stroboscopes — Light Pulses
- 13L6 Optical Filters — Absorption of Light
- 13L7 Specular and Diffuse Reflection of Light
- 13L8 Image Formation with Mirrors
- 13L9 Prisms — Refraction and Dispersion of Light
- 13L10 Lenses — Focusing and Spreading of Light
- 13L11 Interference — Testing Flat Surfaces
- 13L12 Diffraction Grating — Measuring the Wavelengths of Light
- 13L13 Polarization — Glare Reduction
- 13L14 Holography — Three Dimensional Photography
- 13L15 Spectroscopy — Light Analysis
- 13L16 Infrared Radiation Thermometers
- 13L17 Illumination
- 13L18 Single Lens Reflex Camera
- 13N1 Geiger Counters
- 13N2 Penetrating Power of Alpha and Beta Radiation
- 13N3 Radioactivity
- 13N4 Absorption of Gamma Radiation

Prices:
- Concept Modules — $0.80
- Application and Supplementary Modules — $0.40
- Notebook to contain 35 modules — $2.25
- Instructors Guide — $8.00

UTC

PHYSICS FOR THE TECHNICAL STUDENT



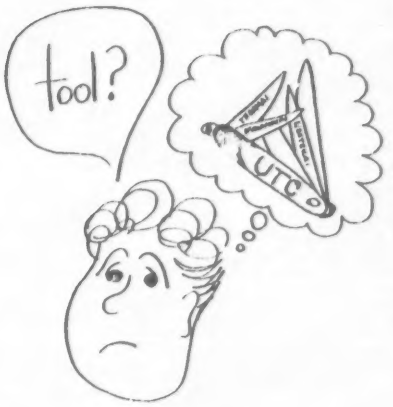
What is UTC?

UTC, which stands for "United Technical Concepts," is the common-sense way to learn PHYSICS, and PHYSICS is where it's at for a tech student.

Thanks. But I want to learn a Technology, no' 'YSICS!

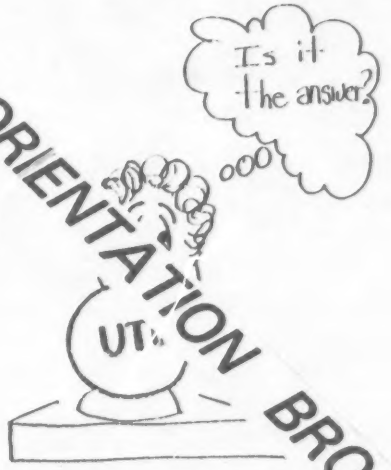
WAIT! You're missing . erybody needs a little physics - especially tech. y too bad so many tech students back a. 's. Or think of it as a hard or boring subject . to view it as a mess of formulas or demonstrat. nthing to do with their real world. They make it . nking it's hard when it's really easy. And it's a. ever we go or whatever we do. UTC - If you will prove this and, at the same time, prov. super "tool" you'll use all the time in your wo.

STUDENT ORIENTATION BROCHURE



A Tool? I thought Physics was something scientists "fiddled" with in laboratories! How does a technician use it?

Good question. Physics is the study of matter and energy, and especially how these two things interact. This study includes a lot of observations and experiments (trying things to see if they work); what you learn from it can be used to understand and describe how things work (or why they don't) and to predict when things are going to happen. Physics, then, is a tool for figuring out what's going to happen before it happens; it's a tool for preventing wrong or bad things from happening; and it's a tool for understanding what's behind problems that you, as a technician, will run into, and for solving those problems.

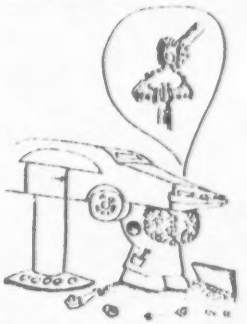


I'm still up tight about taking PHYSICS!

UP-TIGHT? Then UTC is the physics for you. It's designed for folks who can't get excited about a lot of THEORY or another series of PROFOUND lectures. In UTC, everything you do, or read, fits right in with your work as a technician. Try it! You'll like it!

But I thought physics used a lot of math; I already don't like math!

UTC uses math, but not as much as you think, and it's pretty easy. If you've had a year of high school algebra you should be in good shape for UTC. And, just in case you've forgotten some of that algebra, UTC includes some special modules to help you.

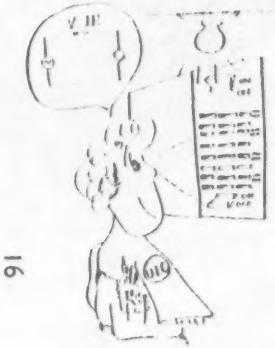


I'm a lot less skeptical, but I'm still ot quite convinced. Are you sure 'S not too Complicated for me?

! Sure, physics can be complicated (and ot UTC. It breaks up the physics you ne. into easy to understand 'concepts' that you'll reme. d use.

Explain UTC organization to me some more.

OKAY. UTC presents the basic rules of how matter and energy behave. It explains how these rules apply in various technical situations. Then it shows how these same rules apply in the four most important energy systems (mechanical, electrical, thermal and fluidal). At the same time, it allows you to see how each of these energy systems fits into a technical application. In short, as soon as you understand how these systems work together, you can understand how a refrigerator works, or an automobile engine, or a hydraulic press, or whatever.



To keep it simple, UTC includes three slightly different parts.

CONCEPT MODULES describe basic concepts of physics (such as FORCE, ENERGY, RATE OF MOVEMENT and so on). Each of these modules shows how a single concept relates to each energy system, and to other concepts. These modules are taught in class, with the instructor showing examples of each concept in everyday use.

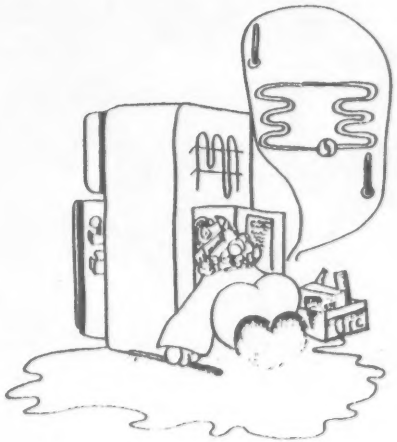
APPLICATION MODULES each describe the use of one concept in a single energy system. For each application module you'll perform a practical experiment so that you really understand how the concept fits into the work you're learning to do.

SUPPORT MODULES offer that help mentioned earlier that you may need to solve a math problem or to read a graph.

*A module is a few pages of text and related material restricted to one concept or principle.

How do I know which modules to study?

The modules you need for your technology have been selected by folks who know your technology forward and backward. That way, students in automotive and those in electrical power or laser technology may all study the same concepts, for example, but each group should have a different set of application modules. As for the support modules, you and your instructor might decide together which ones, if any, you need.



How do I know what to look for as I study UTC?

EASY. Remember to:

- Look for the tie between concept modules and application modules.
- Look for the tie between each new concept you study and those you've studied before.
- Look for ways to apply each UTC concept to what you're learning and doing in your other technical studies.

Well... You do have some good arguments for UTC. 'PHYSICS' isn't my favorite subject yet, but I guess it won't hurt to have a go at UTC.

GOOD! An open mind is important.
Look at the UTC materials. Keep in mind that the idea behind UTC is to make physics easier for you so you can let it work for you.

For additional copies of this brochure contact:
Technical Education Research Center - Southwest
Suite 111
4201 Lake Shore Drive
Waco, Texas 76710

SEVENTEENTH ANNUAL NATIONAL CONFERENCE ON TECHNICAL EDUCATION

MARCH 26-29 1980

NEIL HOUSE
27 SOUTH HIGH STREET
COLUMBUS, OHIO

SPONSORED BY
AMERICAN EDUCATION ASSOCIATION
TECHNICAL EDUCATION DIVISION
AMERICAN VOCATIONAL ASSOCIATION
U.S. OFFICE OF EDUCATION

EDUCATION FOR THE TECHNICAL 80'S

SUBJECT II

"Preparing Technicians for Energy-Related Occupations"

Speaker: Dan Hull, President, Center for Occupational Research and Development

Location: President's Ballrooms East and East Center

NOON - 1:30p.m.
LUNCH AND AWARDS PRESENTATIONS

Location: President's Ballrooms West and West Center

1:30 p.m. - 3:00 p.m.

SECOND GENERAL SESSION

Presiding: Charles O. Whitehead, President, State Technical Institute at Memphis

Recorder: Milton E. Larsen, Professor of Vocational Education, Colorado State University

Host: Fred Yenny, President, Stark Technical College

SUBJECT III

"Cooperation with Industry Through Apprenticeships"

Speaker: Larry L. Whitworth, Dean of Instruction, Community College of Allegheny County-North Campus

SUBJECT IV

"A Technology Transfer Consortium for Business and Industry"

Speaker: Robert Bailey, Director, Program for Energy Resources, Education and Public Service, The Ohio State University

NATIONAL MEETING OF THE AMERICAN ASSOCIATION OF PHYSICS TEACHERS

January 23-25, 1980
Chicago, Illinois

1:00 P.M.—January 23, 1980 **Los Angeles-Miami Room**

SPS INVITED LECTURE

Presiding: *Dion W. J. Shea*, Society of Physics Students, New York, NY 10017

Conversion of Coal to Other Energy Forms—New Uses for an Old Fuel
Nancy M. O'Fallon, Argonne National Laboratory, Argonne, IL 60439

2:00 P.M.—January 23, 1980 **Chicago Ballroom E**

EE INVITED AND CONTRIBUTED PAPERS ON ENERGY-RELATED CURRICULA FOR COMMUNITY COLLEGES (Sponsored by the Committee on Physics in the Two-Year Colleges)

Presiding: *Paul Koblas*, Delta College, University Center, MI 48710

2:00 P.M. EE1 Energy and the Community College (invited, 20 min.)

Pearley Cunningham, Community College of Allegheny County, South Campus, West Mifflin, PA 15122

The physics teacher in the two-year college is in a unique position to make a contribution to understanding and tempering the "energy crisis." Physics teachers were among some of the first academics to call attention to the dwindling of our energy resources by presenting programs such as energy and environment courses. The community college now has the opportunity to follow through with an expanded emphasis on energy conservation, alternate energies, and renewable energy sources. The activities of the South Campus Physical Science and Technology Department in the areas of energy education and, in particular, the college's Energy Management Technician project, will be discussed. The author will also discuss how similar activities might be carried on at other community colleges. Sources of funding, national or regional projects, and cross-departmental programs will be presented.

2:25 P.M. EE2 UTC Physics—A Broad Technical Base for Energy Technicians (invited, 20 min.)

D.M. Hull, General Manager, Technical Education Research Center—Southwest, Waco, Texas
L.S. Pedrotti, Professor of Physics, Air Force Institute of Technology, Dayton, Ohio

Modern equipment associated with energy production and utilization typically consists of systems which include parts of mechanical, electrical, thermal, fluid, and optical subsystems. Frequently systems are controlled by electronic computers or microprocessors. The energy technician must be able to apply these basic principles to new equipment and new problems. Unified Technical Concepts (UTC) simultaneously addresses four principal energy systems—mechanical, thermal, fluid, and electrical—while covering the basic concepts contained in traditional physics courses. The presentation is in modular form, which provides considerable flexibility in designing a suitable physics curriculum for most two-year technicians, particularly energy technicians. The curriculum, testing, evaluation, and revision of UTC was sponsored by the U.S. Office of Education over a three-year period. The UTC program has resulted in 13 concept modules and 180 application modules. In the year since completion, the modules have been adopted by fourteen post-secondary technical institutions throughout the country.